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ORIGINAL RESEARCH ARTICLE

Should Commercial Diagnostic Testing Be Stimulated or Discouraged? Analyzing Willingness-to-Pay and Market Externalities of Three Commercial Diagnostic Tests in The Netherlands

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Abstract

Introduction Consumers may purchase commercial diagnostic tests (CDT) without prior doctor consultation. This paper analyzes three CDT markets—commercial cholesterol tests (CCT), direct-to-consumer genetic health tests (DGT) and total body scans (TBS)—in the context of the universal, collectively financed health care system of the Netherlands.

Methods An online willingness-to-pay (WTP) questionnaire was sent to a representative sample of 1500 Dutch consumers. Using contingent valuation (CV) methodology, an array of bids for three self-tests were presented to the respondents. The results were extrapolated to the Dutch population and compared to current prices and follow-up medical utilization, allowing analysis from a societal perspective.

Results Overall, 880 of 1500 respondents completed the questionnaire (response rate 59%). Of the respondents, 26–44% were willing to pay a positive amount for the CDT. Willingness-to-pay was correlated to age and household income, but not to health status or prior experience with these tests. At mean current prices of €29 for CCT, €229 for DGT and €1,650 for TBS, 3.3%, 2.5%, and 1.1%, were willing to purchase a CCT, DGT, and TBS, respectively. All three CDT resulted in net costs to the health system, estimated at €5, €16, and €44 per test, respectively. Reducing volumes by 90,000 CCTs (19%), 19,000 DGTs (5%) and 4,000 TBSs (2.5%) in 2019 would optimize welfare.

Conclusion Most respondents were unwilling to consume CDT at any price or only if the CDT were provided for free. However, for a small group of consumers, societal costs exceed private benefits. Therefore, CDT regulation could provide small welfare gains.

Key Points for Decision Makers

Commercial diagnostic tests (CDT) may result in additional care utilization in public health systems.

We measured willingness-to-pay for three CDT through questionnaires, and combined these with estimates of follow-up health care use.

All three tests resulted in overuse of CDT from a societal perspective, but the welfare loss is small.

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1 Introduction

An increasing offer of commercial diagnostic tests (CDT) is available for consumers worldwide. Commercial diagnostic tests allow consumers to obtain insight into their health status without prior visit to a doctor or medical specialist. Examples include over-the counter diagnostic tests such as COVID-19-antigen kits, cholesterol tests and allergy tests, but also wearables such as heart monitors and sleep monitors, online orderable commercial tests, such as testing kits for sexually transmittable diseases, health questionnaires and direct-to-consumer genetic tests, and on-site commercial tests, such as COVID-19-PCR tests, fitness tests and total body scans (TBS) [1]. While CDT are—by definition—private markets, they may affect the public health system through follow-up costs; for example doctors' consultations and treatments following positive CDT results [2, 3]. Proponents of CDT advocate benefits of early diagnosis, patient awareness, empowerment, and lifestyle changes, and, as a result, improved health and lower health care costs downstream [2, 4]. Opponents warn for unnecessary medicalization, low-value care and redundant follow-up health care costs [2, 3].

Commercial diagnostic tests are particularly predominant in the USA, where high out-of-pocket spending reduces the public burden of follow-up costs. In contrast, in countries with a broad collective health care system additional follow-up cost-effects are predominantly shared collectively [4]. This may exacerbate externalities in the market for self-tests, and consequently increase potential for market failure. For example, if proponents are right, CDT may lead to early diagnosis, lowering future treatment costs for advanced illnesses, or may promote a healthy lifestyle, which also may lower future health costs. As these are shared collectively, other people benefit from the use of CDT in the form of lower health taxes and premiums, which are not considered in the decision-making process of the potential consumer. In that case, encouraging CDT consumption would enhance total welfare. However, if opponents are correct, CDT may spur unnecessary follow-up tests, consultations, and treatments, boosting health costs for others through increased health taxes and premiums. As potential consumers are unlikely to consider that CDT consumption may also incur costs to others, CDT may be overconsumed from the perspective of society. However, methodology and frameworks to assess the effects of CDT in the context of a universal health system and to inform policy makers have been lacking. In other words, at the margin the costs to society outweigh the private benefits of consumption. These so-called externalities may be a reason for policy makers to intervene into the market [5]. We build upon the theory of externalities to assess the market for CDT and inform policy makers.

Economist Arthur Pigou studied the effects of positive or negative externalities on market outcomes, as shown in Fig. 1. Here, a downward sloping demand curve (green) represents the willingness-to-pay (WTP) for a CDT as a function of the expected benefits, including follow-up treatment effects. The horizontal supply curves show the cost of production, where the middle line (blue) represents the private costs: the price of CDT plus the expected value of copayment in case of follow-up payments. Externalities cause social costs of production to deviate from private costs, either in the form of negative externalities (upper orange line) or positive externalities (lower orange line). If consumption of CDT causes additional costs to the health

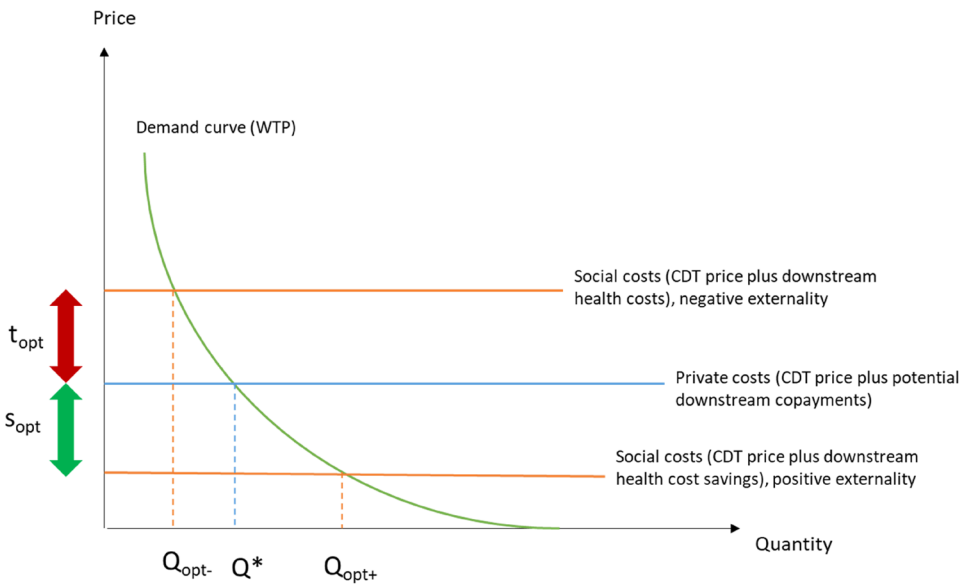

Fig. 1 Marshallian diagram of the market for commercial diagnostic tests (CDT), with a downward sloping demand curve defined by the willingness-to-pay (WTP), and a horizontal supply curve defined by the private costs of CDT, leading to equilibrium market quantity Q*. Potential positive and negative externalities result in suboptimal outcomes, which could be addressed by a tax t_{opt} to restrict use to Q_{opt-} or a subsidy s_{opt} to increase use to Q_{opt+}

system borne by taxpayers, social costs are higher than private costs, leading to overconsumption (Q*minus Q_{opt-}). However, if consumption of CDT leads to cost savings to the health system, which accrue to taxpayers, social costs are lower than private costs, leading to underconsumption (Q_{opt+} minus Q*). Theoretically, Pigouvian taxes (t_{opt}) or subsidies (s_{opt}) equivalent to the size of the externality correct market outcomes [5].

Willingness-to-pay may be modeled as a function of perceived personal net benefits of consumption. Economic theory suggests that upon the consumption decision, consumers weigh perceived costs and benefits of consumption, which includes health-related benefits but also less tangible private benefits and costs. Health benefits may follow from early diagnosis and treatment as well as lifestyle changes resulting from diagnosis of (risk of) diseases. Consumers may also include potential negative health benefits, e.g., risk of overtreatment, in their consumption decision. Less tangible private benefits may include increased certainty, ease of mind, or feeling in control of one's own health, amongst others. These may also be negative, like additional stress or uncertainty following positive test results, especially in the case of false-positives [6, 7]. These benefits, positive or negative, are incorporated into the willingness to pay (WTP) for CDT. Willingness to pay may be influenced by income, health state, previous experience with tests, family history, and other individual characteristics [8].

Willingness-to-pay therefore, is related to traditional cost-effectiveness measures, such as cost-per-quality-adjusted life year (QALY), in the sense that marginal effectiveness of CDT may be incorporated as part of the perceived benefits. However, since additional private consumer values apply to the WTP but are excluded in cost-effectiveness values, WTP for a CDT may be higher than the WTP for any QALY gains due to CDT consumption. Furthermore, cost-effectiveness measures are generally used to evaluate whether a treatment should be reimbursed collectively, implying that the marginal cost-effectiveness value of a representative person can be used as threshold. However, this does not apply to private markets, where consumption may be valuable for some but not all persons, e.g., those who value health benefits relatively highly, or those who value CDT intrinsically highly [9]. Therefore, CDT with unfavorable incremental cost-effectiveness ratios may still have net positive consumption value in the private market. However, in this case externalities should be taken into account [10].

This paper studies CDT markets in the context of the Netherlands, having a universal health system covering over 17 million inhabitants. The Netherlands has a broad benefits package (including general physician [GP] care, hospital care, medication), financed collectively through a mix of insurer premiums, employer contributions and general taxes. Cost sharing constitutes a mandatory deductible of €385 and a voluntary supplementary deductible of €100–€500, while additional cost sharing is limited to long-term care and specialty (brand) medications. The Netherlands is characterized by a GP gatekeeping system, with patients needing a GP-referral to consult inpatient medical specialists. General physician visits are free of charge and exempt from the deductible [11, 12]. The Dutch government offers a number of free population-wide screening programs, such as breast cancer screening, human papillomavirus (HPV) screening, newborn screening and colorectal cancer screening [13]. Nevertheless, the market for consumer CDT is small but growing in the Netherlands [1].

The aim of the paper is to explore externalities in three CDT markets. The aim involves three research questions: (1) Are externalities present in the market for CDT, and what is the direction and size of these externalities in the Netherlands? (2) What is the WTP for CDT in the Netherlands? (3) Given current and future prices of CDT, what would be the optimal level of consumption from a societal perspective? The results may inform policy makers on whether regulation of these private markets may improve welfare.

2 Methods

2.1 Literature Search

We performed a rapid review to map existing evidence regarding follow-up health care use for CDTs. We targeted cost-effectiveness studies that evaluate CDTs. We included a broad selection of CDTs based on existing overviews. We developed a search strategy consisting of combination of keywords, thesaurus terms and synonyms of CDT and cost effectiveness (Appendix 1). We searched the first ten pages (100 hits) of Pubmed, Google and Google Scholar between May and July 2021. We consulted experts for key articles and used forward and backward snowballing methodology to find relevant and recent articles.

2.2 Case Study Selection

Based on existing overviews of CDTs and evidence on follow-up costs, three CDTs were selected for this study based on representativity and recognizability: in increasing order of invasiveness and price: over-the counter commercial cholesterol tests (CCT), direct-to-consumer genetic health tests (DGT) as example of a commercial online orderable test, and total body scans (TBS) as representative of on-site commercial diagnostic test.

2.2.1 Commercial Cholesterol Tests

Commercial cholesterol tests (CCT) are sold over the counter in Dutch drug stores for prices between €15–€25 [14]. Many types of cholesterol tests are available that differ on accuracy, types of cholesterol molecules and additional information provided, such as lifestyle advice. Testing includes running a blood sample through a test kit and manually or electronically reading the results [15, 16].

2.2.2 Commercial Genetic Health Tests

Numerous direct-to-consumer genetic health tests (DGT) are available in the Netherlands, generally marketed by foreign-based providers. The majority of genetic tests focus on ancestry or relatedness, while few DNA tests provide information on disease-associated genes. The US regulation has only recently allowed commercial testing of specific disease-related genes, which also influences availability in the Netherlands [2]. Testable diseases include, among others, cancers of the lung, breast, ovary, prostate, stomach, intestine, liver and esophagus, as well as a number of chronic conditions such as circulatory diseases, type 2 diabetes, Alzheimer's disease, Parkinson's disease, rheumatoid arthritis, cerebrovascular diseases and osteoporosis. Specific allele or nucleotide occurrences within certain genes may increase the likelihood of future disease development, although lifestyle factors also have major influence. DNA tests require posting saliva samples to a laboratory abroad for examination, costing between €50–€500, depending on modalities [17]. Results are generally presented as relative chances of acquiring specific diseases given allele occurrence. Occasionally, additional health advice is provided, including lifestyle recommendations or consultation with an expert.

2.2.3 Total Body Scans

Total body scans may include a full physical examination, ECG, MRI and CT-scans, blood, urine and stool testing and consultations with medical specialists, targeted at early diagnosis and second opinions on undiagnosed complaints. Total body scans take place at commercial clinics. Currently, Dutch law prohibits use of radiation imaging techniques for commercial tests[1], but allowing TBS in the Netherlands has been a political debate since 2015 [18]. Total body scans are currently marketed for around €500–€2000, depending on included features, with imaging taking place in clinics across the border in Germany and Belgium (travel time approximately ≤ 2 h).

[1] Wet op het Bevolkingsonderzoek

For each of these tests, we collected information on providers, characteristics, and prices targeting the Dutch health care market. Based on this information, we constructed case descriptions and set base bidding levels for our questionnaire.

2.3 Questionnaire Development

A structured questionnaire was developed to measure consumers' WTP of three case studies. To this aim, a contingent valuation (CV) methodology was applied [19–24]. Contingent valuation is considered more sensitive for bias compared to more elaborate elicitation methods, but an advantage could be the higher respondent numbers due to lower burden of response, especially if bias is explicitly addressed in CV design. Common biases include starting point bias, where the respondent's WTP height is influenced by the starting bid height, or range bias if respondent is more likely to settle on a middle answer [10, 25, 26]. To correct for these biases, we designed three bidding procedures. In the first bidding procedure, respondents were given a low starting bid in euros and were asked whether they were willing to purchase the CDT priced at this amount. If yes, a new bid was offered double the previous until respondents were unwilling to purchase the CDT for the given bid, or until the maximum amount was reached, set at eight times the market price. To reduce anchoring effects, future bids were not shown unless current bids were not accepted. The second bidding procedure started with a bid amount twice as high and ended at 16 times the mean market price. The third bidding procedure started at eight times the market price, and if respondents were not willing to purchase the CDT at that amount, a new bid half the amount was shown, until the respondent accepted the bid or a bid of zero was reached. Each respondent received one of three bidding procedures per CDT, but the order was randomized over the three CDTs while ensuring that each respondent received all three bidding procedures once. This allowed us to correct for respondent fixed effects. To this aim, three versions of the questionnaire with differently ordered CV arrays were randomly distributed among respondents.

The bidding procedures were followed by the question whether respondents were willing to consume the CDT, and if so, at what maximum euro amount [27]. After the bidding, consumers were asked about their thoughts and motivations through open text fields. Furthermore, respondents were asked about prior experience with the CDT and motivation to consume the CDT, as well as background characteristics such as household income, health status, and health use. The online survey consisted of 23 questions (see Appendix 2), with a median completion time of 6 minutes.

The online questionnaire was sent to a sample of 1500 panel members from the Dutch Health Care Consumer Panel

of Nivel (Netherlands Institute for Health Services Research). The panel was representative regarding gender and age for the Dutch adult population. The Consumer Panel aims to measure opinions on, and knowledge of, health care as well as the expectations of, and experiences with, health care among a cross-section of the Dutch population [28, 29]. The panel is a so-called access panel consisting of a large number of people who have agreed to answer questions on a regular basis. Many background characteristics of the panel members are known such as their age, gender and highest level of education completed. At the time of this study (August 2021), the Consumer Panel consisted of approximately 11,000 people aged 18 years and older. On average, an individual panel member receives a questionnaire about three to four times a year. There is no possibility of people signing up for the panel on their own initiative. The Dutch Health Care Consumer Panel is renewed on a regular basis.

Data were pseudonymized and processed according to the Consumer Panel privacy policy, which complies with the General Data Protection Regulation [30]. According to Dutch legislation, neither obtaining informed consent nor approval by a medical ethics committee is obligatory for carrying out research in the panel [31]. Participation in the panel is voluntary. Panel members are not forced to participate in surveys, and they can stop their membership of the panel at any time without mention of any reason for stopping.

2.4 Willingness-to-Pay Analysis

We obtained two WTP values per respondent per CDT: the bidding array rendered a final accepted bid, in discrete amounts. An open-ended follow-up question provided a second stated WTP value on a continuous scale. In theory, the open-ended stated WTP should be between the final accepted (rejected) bid and the first rejected (accepted) bid, although discrepancies may occur in practice [9]. The open-ended continuous stated preference was used unless this value was inconsistent with the bidding outcome (e.g., when the open-ended stated preference was below the bidding outcome or more than double the bidding outcome). In that case, the discrete final accepted bid was used as WTP.

Responses were analyzed using multinomial logistic regression analysis and multivariate ordinary least squares (OLS) regression analysis. A multinomial logistic regression analysis estimated the odds of belonging to the group of respondents having a positive WTP (WTP > 0), a WTP of zero (WTP = 0) or being unwilling to consume at any price (WTP =.). In the second stage, a linear regression was estimated using WTP height and explanatory variables among the fraction with positive WTP. In both stages, population weights were applied based on age and gender, and, alternatively, on age, gender, income, education and ethnicity. Regression formulae for the two-stage model are given below:

$$\ln\left(\frac{P(\mathrm{WTP}=k)}{P(\mathrm{WTP}>0)}\right)=\alpha_i+\beta_i\boldsymbol{X}+\gamma_i\boldsymbol{Z} \tag{1}$$

$$\ln\left(\mathrm{WTP}_j\right)=\alpha_j+\beta_j\boldsymbol{X}+\gamma_j\boldsymbol{Z}+\varepsilon_j \tag{2}$$

In (1), a multinomial logistic model is fitted to estimate the probability of being in group $k = 1$: having a WTP of zero (WTP = 0) or being in group $k = 2$: unwilling to consume (WTP = .) relative to the baseline group of respondents with a positive WTP (WTP > 0). The probability of being part of a group is modulated by a vector **X** of questionnaire characteristics and a vector **Z** of personal characteristics. Next, we estimate the effect of confounders on WTP height using a subset of respondents (j) that reported a positive WTP. To normalize the skewed distribution of WTP values, a log transformation was performed.

As a robustness check, a Tobit model was estimated on all non-missing data, including WTP=0 [32]. Furthermore, as a sensitivity check, WTP values of >25% of monthly income were removed from the analysis [33].

The vector $\boldsymbol{X}$ contains two structural questionnaire characteristics: a dummy low starting bid, which is one if the respondent received a low bid-series and zero if the respondent received a high bid-series, and a dummy downwards bidding procedure, which is one if the respondent received a bidding series moving from high to low values, and zero if the respondent received a bidding series moving from low to high values. The vector $\boldsymbol{Z}$ contains the following variables: income, education, gender, ethnicity, previous consumer experience, health status and whether the deductible applied. Income was operationalized into 15 categories, ranging from gross monthly household income of under €300 to over €6000. Education contains the categories lower education (none, primary school or prevocational education), intermediate education (secondary or vocational education), and higher education (professional higher education or university) [34]. Ethnicity is 1 if non-Dutch. Health status has previously been related to CDT-use in the Netherlands [1]. Health status is measured in the questionnaire as self-reported health on a 5-point Likert scale. Furthermore, respondents were asked if they completed the mandatory deductible or were expecting to complete the mandatory deductible, resulting in a variable which is one if respondents expected to experience the effects of the deductible in any potential follow-up costs.

A correction procedure was designed to correct the WTP value for bias due to survey characteristics. For example, respondents receiving high starting bids may overstate their true WTP, while respondents receiving low starting bids may understate their true WTP [10, 25, 26]. We estimate the percentage difference between bids over each bidding procedure and assume that the true WTP lies

exactly in between. When the difference between bidding procedures is estimated at β_1, c.q. Eq. 2, then the WTPs elicited from surveys with a high starting bid are corrected downwards by $\frac{1}{2}\beta_1$, and the WTPs elicited from surveys with a low starting bid are corrected upwards by $\frac{1}{2}\beta_1$. The same procedure applies for upwards bidding procedure versus downwards bidding procedure. To estimate β_j, the baseline model without respondent characteristics $\boldsymbol{Z}$ is estimated (see Appendix 3).

Next, a demand curve is fitted to the corrected WTP using OLS.

$$\ln\left(c\mathrm{WTP}_j\right) = \theta_0 + \theta_1 \ln\left(n_j\right) + \in_j, \tag{3}$$

where n_j is the order of all respondents with positive WTP_j, ordered from high to low WTP. The demand curve is assumed to be logarithmic of the form $P = \frac{e^{\theta_0}}{Q^{\theta_1}}$, rendering asymptotes along the x-axis and y-axis. The demand equation is normalized to the interval between 0 and 1 to facilitate extrapolation to the full population.

2.5 Open Response Thematical Analysis

Respondents were given the opportunity to comment on their choice of WTP for each of the three CDTs. Due to the large number of responses, we incorporated a qualitative analysis ex post to collect reasons and motivations behind WTP choices. All available responses were analyzed through thematic coding in MaxQDA. Two researchers coded the free texts using deductive coding based on grounded theory [35]. Through iterative rounds, codes were compared, synchronized and grouped into common themes [36]. Codes were analyzed quantitatively to infer effects of respondents' motivations on WTP as well as differences in motivations between CDT.

2.6 Estimating Externalities

For each CDT, estimates of follow-up utilization and potential cost savings were extracted from the literature. These data were applied to a hypothetical cohort of 10,000 consumers to calculate follow-up utilization effects per consumer (Appendix 4). Using Dutch tariffs, total costs were calculated. By using information on cost sharing, total follow-up costs were subdivided into private costs and public costs. The public cost per consumer, combined with current CDT prices, was plugged in the demand function to estimate actual and optimal CDT utilization. In accordance with Dutch guidelines, we will use a discount rate of 4% for future monetary costs and benefits [37].

Table 1 Sample characteristics

Total N	Full sample 1500	Respondents (%) 880 (59%)	Dutch population 13,950,083
Age			
18–39 years	515 (34%)	217 (25%)	34%
40–59 years	426 (28%)	261 (30%)	33%
60–79 years	481 (32%)	350 (40%)	27%
80–105 years	78 (5%)	52 (6%)	6%
Gender			
Female	750 (50%)	457 (52%)	51%
Education			
Low	106 (7%)	72 (8%)	27%
Intermediate	628 (42%)	378 (44%)	42%
High	747 (50%)	416 (48%)	32%
Ethnicity			
Non-Dutch	132 (9%)	82 (9%)	19%
Net monthly household income			
< €1500	185 (12%)	77 (9%)	21%
€1500–2500	438 (29%)	199 (23%)	40%
€2500–3750	403 (27%)	206 (23%)	29%
> €3750	413 (28%)	239 (27%)	10%
Not reported	61 (4%)	159 (18%)	

3 Results

3.1 Descriptive Statistics

In total, 880 respondents filled in the questionnaire (59%), 32 (4%) of whom partly filled in the questionnaire (Table 1). This is in line with previous panel response rates [34, 38, 39], and on the high end[2] for CV studies [40]. Relative to the full sample, fewer people aged 18–39 completed the questionnaire (25% vs 34%), with corresponding effects on education and income. Relative to the Dutch population, age category 60–79 is overrepresented and 18–39 years is underrepresented. Using age and gender weights, responses were weighed to reflect demographics of the full Dutch population. Also, the full sample of 1500 panel members contained fewer persons with low education, low income and non-Dutch ethnicity than the population as a whole. As a robustness check, we use extended population weights including education, income and ethnicity weights.

3.2 Willingness-to-Pay for Self-Tests

Of 880 respondents, about one-third is unwilling to consume CCT even at a price of zero (Table 2). This is larger for DGT

[2] Of 62 CV studies included in a recent review, 37 studies have lower participant numbers.

Table 2 Descriptive statistics

Unwilling to consume at any price	CCT	298 (33%)
	DGT	457 (50%)
	TBS	374 (40%)
Positive willingness to pay	CCT	385 (44%)
	DGT	226 (26%)
	TBS	325 (37%)
Mean (median) WTP if WTP>0	CCT	€11.65 (€7.19)
	DGT	€117.22 (€45.01)
	TBS	€233.10 (€102.37)
Consumed in last year	CCT	13 (1.5%)
	DGT	4 (0.5%)
	TBS	8 (1.0%)
Health state	Excellent	49 (5.9%)
	Very good	242 (29.1%)
	Good	384 (46.3%)
	Mediocre	142 (17.1%)
	Bad	14 (1.6%)
Deductible left	Yes	474 (54%)

Percentages are weighted to be representative for the Dutch population

CCT commercial cholesterol tests, *DGT* direct-to-consumer genetic health tests, *TBS* total body scan, *WTP* willingness-to-pay

(50%) and TBS (40%). Furthermore, 22% of respondents are only willing to consume a cholesterol self-test at a price of zero. This is 22% for DGT and 20% for TBS. The remainder have a positive WTP (CCT:44%; DGT:26%; TBS:37%). Mean (median) WTPs in this subgroup were €11.65 (€7.19), €117.22 (€45.01) and €233.10 (€102.37) for CCT, DGT and TBS, respectively. Figures 3.1a–c in Appendix 3 show that WTP values display a logistic functional form.

Table 3 shows the results of the two-stage model. Columns 1 and 2 show the first stage MLR estimates, i.e., the odds of being in the group of persons unwilling to consume a CDT (WTP =.) or in the group of persons willing to consume but only if the CDT is free (WTP=0) vis-à-vis the group of persons with positive WTP (WTP > 0, baseline group). Column 3 shows the estimates of the second stage OLS regression relating the height of the WTP to independent variables for the subgroup WTP > 0. The bidding procedure has a significant influence on WTP height, especially whether bidding is upwards or downwards. For example, respondents receiving a downwards bidding procedure have a 50% increased chance of having a positive WTP. Furthermore, given a positive WTP, a downwards bidding procedure roughly doubles the WTP.

A higher age will increase the odds of having a WTP of zero. Furthermore, older respondents are less willing to perform DGT. For CCT and DGT, income is correlated to WTP height, where an increase in monthly income of €1000 increases WTP by 9–10%. The results are robust to the functional form of the estimation and population weights (Tables A3.1–3.2 in Appendix 3).

Next, WTP values were corrected for bias, followed by estimation of the demand equations using OLS (Tables A3.3 and A3.4 in Appendix 3). The following demand equations were obtained:

$$p^{\mathrm{CCT}} = \frac{e^{0.60}}{x^{0.81}} \text{ for } x = [0, 0.44] \tag{4}$$

$$p^{\mathrm{DGT}} = \frac{e^{0.99}}{x^{1.21}} \text{ for } x = [0, 0.26] \tag{5}$$

$$p^{\mathrm{TBS}} = \frac{e^{2.78}}{x^{1.03}} \text{ for } x = [0, 0.37] \tag{6}$$

The demand equations should be interpreted as the fraction of the population (x) that is willing to consume a CDT at price p. The demand equations are bounded by the fraction with a positive WTP (see Table 2), and by a price range of $< 0, \infty >$.

3.3 Explanatory Analyses

Of 880 respondents, 466 (53%) commented on their choice in the free comment section of at least one CDT. These motivations were coded and analyzes per CDT, rendering 53 codes (Table A3.5 in Appendix 3). Codes were categorized hierarchically into common themes, as displayed in Table 4. Codes were labeled as positive attitude towards CDT, negative attitude towards CTD and doubt. For positive attitudes, second-level hierarchical distinctions were made between medical benefits (prevention, early detection, health improvements) and non-medical benefits (interest, comfort, trust, experience). For negative attitudes, three second-level hierarchies were distinguished: irrelevance, conditionality and objectional. Irrelevance relates to the CDT being not relevant for the responder at the moment (e.g., due to good health, medical supervision, or old age). Conditionality refers to respondent commenting CDT consumption depends on circumstances and context (e.g., under supervision of a (family) doctor, distributed at low cost/free, or only if specific complaints arise). Objectional includes respondents having objections regarding CDT (e.g., relating to reliability/trust or fear of procedure/outcomes). The distribution of comments over these themes differs per test. A larger percentage of respondents reported positive attitudes towards TBS (Table 4), with prevention and potential health gains as frequently mentioned motivations. For CCT, respondents more often found tests irrelevant for their situation, e.g., being in good health or already being under medical

Table 3 Explanatory two-stage regressions on willingness-to-pay for three CDT

	CCT			DGT			TBS		
	Multinominal logistic regression (MLR)		Second stage OLS (WTP>0		Multinominal logistic regression (MLR)	Second stage OLS (WTP>0)	Multinominal logistic regression (MLR)		Second stage OLS (WTP>0)
	1a. (WTP=.)	2a. (WTP=0)	3a.	1b. (WTP=.)	2b. (WTP=0)	3b.	1c. (WTP=.)	2c. (WTP=0)	3c.
Low starting bid	− 0.32 (0.25)	− 0.004 (0.23)	− 0.12 (0.12)	− 0.11 (0.27)	0.03 (0.24)	− 0.56*** (0.17)	− 0.25 (0.25)	− 0.41 (0.23)	− 0.30* (0.15)
Downwards bidding procedure	− 0.57* (0.25)	− 0.53* (0.23)	1.05*** (0.11)	− 0.77** (0.28)	− 0.56* (0.23)	0.84*** (0.16)	− 0.86** (0.28)	− 0.37 (0.23)	0.53** (0.13)
Gender	− 0.46* (0.21)	0.09 (0.19)	− 0.05 (0.09)	− 0.37 (0.23)	0.16 (0.19)	0.07 (0.13)	− 0.32 (0.23)	0.43* (0.19)	0.23 (0.12)
Age	0.007 (0.006)	0.041*** (0.006)	0.004 (0.003)	0.020** (0.007)	0.047*** (0.006)	− 0.002 (0.004)	0.013 (0.007)	0.062*** (0.006)	0.001 (0.003)
Education									
Low (baseline)									
Medium	0.3 (0.4)	0.39 (0.38)	-0.08 (0.2)	0.96* (0.49)	− 0.01 (0.38)	0.09 (0.27)	− 0.42 (0.43)	− 0.47 (0.4)	0.04 (0.29)
High	− 0.25 (0.42)	0.33 (0.39)	0.02 (0.19)	0.56 (0.51)	0.67 (0.39)	0.21 (0.27)	− 0.88 (0.45)	0.04 (0.41)	0.05 (0.29)
Income (*€1000)	− 0.05 (0.08)	0.06 (0.07)	0.09** (0.03)	− 0.08 (0.08)	0.05 (0.07)	0.10* (0.05)	− 0.11 (0.08)	0.01 (0.07)	0.05 (0.04)
Health state	0.13 (0.22)	0.15 (0.2)	− 0.01 (0.12)	0.46 (0.32)	0.18 (0.2)	0.11 (0.12)	0.1 (0.26)	0.23 (0.2)	− 0.03 (0.12)
Full deductible	0.87*** (0.24)	0.2 (0.22)	− 0.11 (0.11)	0.12 (0.26)	− 0.07 (0.22)	− 0.18 (0.16)	0.31 (0.25)	− 0.16 (0.22)	− 0.08 (0.14)
Prior experience	− 0.09 (0.7)	− 1.01 (0.86)	0.09 (0.31)	− 0.61 (1.32)	− 1.78 (1.37)	0.85 (0.61)	− 0.05 (1)	− 0.69 (1)	0.86 (0.56)
Self-reported health									
Poor (omitted)									
Mediocre	− 0.03 (0.63)	− 0.37 (0.59)	0.19 (0.36)	1.72 (0.93)	0.77 (0.58)	0.21 (0.37)	0.63 (0.73)	0.31 (0.58)	− 0.66 (0.34)
Good	− 0.64 (0.47)	− 0.91* (0.42)	− 0.02 (0.25)	0.98 (0.64)	0.46 (0.41)	− 0.01 (0.26)	0.76 (0.54)	− 0.04 (0.41)	− 0.14 (0.24)
Very good	− 0.68 (0.42)	− 1.14 ** (0.37)	0.17 (0.21)	0.23 (0.48)	− 0.03 (0.36)	− 0.14 (0.23)	0.42 (0.5)	− 0.09 (0.36)	− 0.19 (0.22)
Excellent (baseline)									
Constant	− 0.9 (1.2)	− 2.7** (1.1)	1.1 (0.6)	− 3.6* (1.7)	− 3.2** (1.1)	2.9 (0.7)	− 1.0 (1.3)	− 3.8*** (1.1)	4.6*** (0.7)
N	699		334	699		211	699		309
(Pseudo) R^2	0.0834		0.3172	0.0906		0.1598	0.127		0.0764

Percentages are weighted to be representative for the Dutch population

CCT commercial cholesterol tests, *CDT* commercial diagnostic tests, *DGT* direct-to-consumer genetic health tests, *MLR* multinominal logistic regression, *OLS* ordinary least squares, *TBS* total body scan, *WTP* willingness-to-pay

Table 4 Relative distribution of qualitative themes over three CDT

First-level theme	Second-level theme	Third-level theme	CCT	DGT	TBS	Total
Positive	Medical benefits		27%	24%	48%	99
	Nonmedical benefits		35%	26%	39%	120
	Test performed		32%	56%	12%	25
Doubt			0%	76%	24%	17
Negative	Conditional	Medical supervision	59%	23%	18%	245
		Regulation	48%	21%	31%	312
		Situational	34%	28%	37%	102
	Irrelevant	Already under medical supervision	88%	5%	8%	241
		Good health	58%	14%	28%	185
		Irrelevant/not interested	16%	45%	39%	147
		Old age	0%	29%	71%	7
	Objectional	Fear of outcomes	10%	62%	29%	256
		Lack of trust	34%	44%	22%	392

CCT commercial cholesterol tests, *CDT* commercial diagnostic tests, *DGT* direct-to-consumer genetic health tests, *TBS* total body scan, *WTP* willingness-to-pay

treatment for related complaints. Furthermore, a large proportion of responses suggested that these tests be performed by a GP or medical specialist. Besides doubting usefulness of CCT, a large proportion of respondents suggested that insurers should reimburse these tests. For DGT, respondents more often reported objections to the test, such as unwillingness to know the outcome, doubts on usefulness and fears of elevated uncertainty. Explanatory analyses (Table A3.6 in Appendix 3) show that a negative view was significantly associated with lower chance of having a positive WTP, and a positive view was significantly associated with a higher chance of having a positive WTP. No significant effect on the size of the WTP was found.

3.4 Market Externalities

3.4.1 Commercial Cholesterol Tests

While cardiovascular prevention programs have been recommended for high-risk patients, cholesterol screening under the non-risk population has not been found to be cost effective under Dutch guidelines. For example, cholesterol screening in not-at-risk US populations renders cost effectiveness of $25,198 to $50,871 per quality-adjusted life year (QALY), while at-risk population displays significantly more beneficial cost-effectiveness ratios [41].

Estimation of follow-up health utilization related to self-test use is challenging, as most studies focus on patients at risk or with a clinical indication, which may not be the representative consumers of CCT. Therefore, we focus on descriptive studies that include willing consumers or subjects representative of the population. A US-based study on cholesterol screening found a positive test rate (low-density lipoprotein [LDL] of > 130) of between 29.8 and 30.7% [42]. The authors found that for every dollar spend on preventative treatment, 36 cents were saved on treatment costs of myocardial infarction, strokes, and other cardiovascular diseases. A similar recoup of 24 cents per dollar spend on preventative treatment was reported by Choudry et al, 2011. A 1996 study providing free cholesterol tests at a pharmacy for interested consumers found elevated cholesterol levels in 42 of 106 consumers (40%) [43]. Of these, 20 (48%) received prescriptions for lipid-lowering drugs. Applying these findings to the Dutch situation, we assume:

additional GP checkups twice a year for patients with high cholesterol costing €9.97 per consultation (2019 prices) for 40% of consumers
use of lipid-lowering drugs for 19% of consumers, costing €14.71 annually (2019 prices)
savings on secondary treatment of 24 cents for every euro spend on primary CVD-prevention in the consumer group, accruing €1.93 per consumer.

Using these figures, CCTs lead to an estimated follow-up cost of €6.12 per consumer (Appendix 4). Given that 46% of the respondents indicate they have depleted the deductible, and that GP consultations are exempt from the deductible, an estimated €0.76 of €6.12 is paid for out-of-pocket (12%). The net externality is estimated at €5.36 per consumer, given a 1-year time horizon (€4.50–€7.12 under different assumptions, data not shown).

3.4.2 Direct-to-Consumers Genetic Health Tests

Little information is available on follow-up costs of DGT. A 2010 study inferred follow-up costs of DGT genetic tests

Table 5 Solving for the social optimum for the Netherlands

	CCT	DGT	TBS
Mean market price	€29	€229	€1650
Demand equation	$p^{CCT} = \frac{e^{0.60}}{x^{0.81}}$	$p^{DGT} = \frac{e^{0.99}}{x^{1.21}}$	$p^{TBS} = \frac{e^{2.78}}{x^{1.03}}$
Private quantity	459,975 (3.30%)	354,469 (2.54%)	156,832 (1.12%)
Total (public) follow-up costs per unit consumed	€6.12 (€5.36)	€23.24 (€15.87)	€54.71 (€43.67)
Socially optimal Q	373,185 (2.68%)	335,376 (2.40%)	152,906 (1.10%)
Difference	−86,790 (−18.9%)	−19,093 (−5.4%)	−3926 (−2.5%)
Net societal costs of CDT	€ 232,596	€ 151,502	€ 85,727
Total follow-up costs (public+private)	€ 2,812,811	€ 8,238,645	€ 8,580,672
Total public costs to the health system	€ 2,465,465	€ 5,625,422	€ 6,848,854

CCT commercial cholesterol tests, *CDT* commercial diagnostic tests, *DGT* direct-to-consumer genetic health tests, *TBS* total body scan, *WTP* willingness-to-pay

by surveying health professionals, finding 22 cases with follow-up costs between $40 and $20,600 [44]. However, the percentage of consumers that seek referral remains unclear. Follow-up costs may include further genetic testing, mammography, CT/MRI chest scan, prostate-specific antigen (PSA) testing and CA-125 test [44]. Furthermore, numbers are relatively low. A 2016 study reports that 10.7% of consumers shared their results with a medical professional [45]. However, it is unclear whether this occurred during regular visits, or whether new visits were initiated by consumers. Furthermore, it was not disclosed which medical professional was contacted. A 2019 survey from Australia reports that 55 of 205 users of DGT report seeing a health professional (27%). This resulted in medical treatment in about one-third of the cases [46]. Following pharmacogenomic self-tests, 5.6% of consumers reported changes in prescription medication, generally following doctors' consultation [47]. A 2019 survey of US doctors found that 40% of DGT consumers received additional referrals, 78% of whom were referred to a clinical geneticist [48].

Using the limited data, we conservatively assume that 10.7% of consumers visit a GP as result of DGT consumption [45], resulting in additional referrals in 40% of GP visits [48]. Referrals include further genetic testing (78%), and additional tests (22%), including mammography, CT/MRI chest scan, PSA testing and CA-125 test [44, 48]. Any treatments following potential positive results of these additional tests are not considered. Using these parameters, externalities are estimated at €16 per consumer (Appendix 4).

3.4.3 Total Body Scans

For TBS, a high percentage of positive test results may be expected, most of which will be false positives. For example, a study from 2005 estimates a positive rate of whole-body CT-scanning of 93%, comprising of 91 percent of false-positives and 2 percent of true positives [49]. Follow-up costs of additional screening and biopsies totaled $5 per patient—or $296 per true positive patient—rendering cost effectiveness of $151,000 per QALY. This would not be considered as cost effective under current Dutch reference values of €20,000 per QALY for screening interventions.

A 2020 study on TBS in the Netherlands and Germany found that 13% of consumers experienced positive test results, 9% of whom were followed-up with a GP or medical specialist consultation [50]. Applying 2019 Dutch tariffs on follow-up utilization of this study (see Appendix 4) renders an estimated €55 in collective medical follow-up costs after TBS if the deductible had been depleted and €34 if the deductible still applied. Assuming 46% of the respondents had depleted the deductible, the net externality is estimated at €44 per TBS consumed.

3.5 Solving for the Social Optimum

Mean prices offered by the dominant provider(s) are €29 for CCT[3], €229 for DGT[4], and €1650 for TBS[5] (2022 prices). Plotting these prices into the demand functions (4–6) renders estimated private quantity of 3.30%, 2.54% and 1.12% of the population purchasing a CDT, respectively. With a population aged 18+ of 13.95 million in 2019[6], this would translate to quantities of 459,975 CCTs, 354,469 DGTs and 156,832 TBSs. Solving the demand function for the societal costs (market price plus externality) renders socially optimal quantities of 373,185 CCTs, 335,376 DGTs and 152,906 TBSs (Table 5). The difference between the socially optimal quality and the estimated private quantity is − 86,790

[3] Cholesterol Test – Thuis meten van HDL- en LDL-waarden | cerascreen checked on 27-01-2022; excluding shipping costs

[4] Wat kost een DNA-test? (igene.nl) checked on 27-01-2022

[5] Bodyscan | 5 gerichte MRI-scans | Prescan checked on 27-01-2022 Total Bodyscan overzicht en prijzen - Total Bodyscan checked on 27-01-2022

[6] StatLine - Bevolking op 1 januari en gemiddeld; geslacht, leeftijd en regio (cbs.nl)

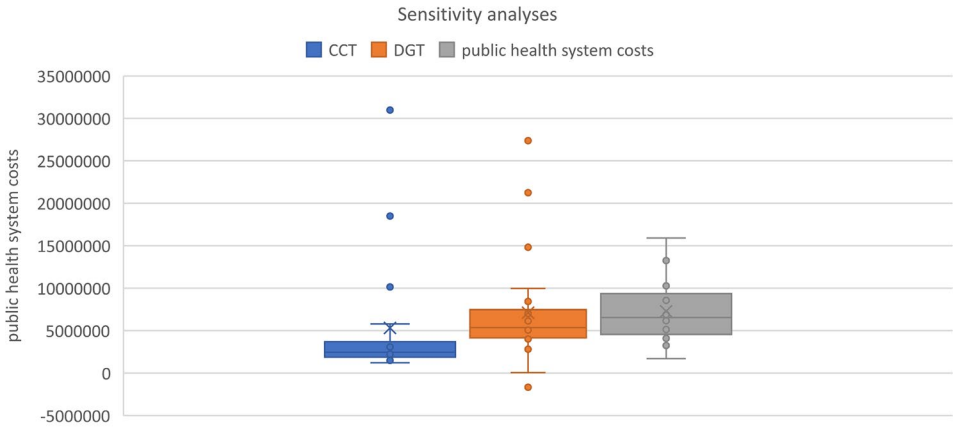

Fig. 2 Boxplot of total public health system costs from sensitivity analyses on price, externality, duration of benefits and alternative specifications. *CDT* commercial diagnostic tests, *WTP* willingness-to-pay

(−18.9%) for CCT, −19,093 (− 5.4%) for DGT and −3926 (− 2.5%) for TBS. The deadweight loss (i.e., net societal costs of CDT) can be approximated by ½* (public follow-up costs per unit consumed)*(private quantity—socially optimal *Q*). The deadweight loss is estimated at €232,596, €151,502 and €85,727, respectively. Total follow-up costs to the health system, including private copayments, are estimated at € 2,812,811, € 8,238,645 and € 8,580,672. Public spillover costs of CDT (excluding cost sharing) to the health system are €2,465,465, €5,625,422 and €6,848,854, respectively.

Sensitivity analyses tested alternative scenarios: (1) Price of CDT is 10%, 25%, 50% higher/lower. (2) Follow-up costs are 10%, 25%, 50% higher/lower. (3) Additional costs/benefits materialize in the long term (5, 10, 20 years). (4) Demand function is discontinuous and directly taken from raw WTP data. (5) Extended population weights are used. (6) Excluding WTP values over 25% of monthly income. The outcomes in terms of public costs of CDT to the health system are presented in Table A3.7 in Appendix 3 and plotted in Fig. 2. The results are most sensitive to the assumptions of additional follow-up costs or benefits in the long run, and less sensitive to changes in current prices, externality costs, different population weights or alternative demand function specification. Removal of WTP values over 25% of monthly income primarily reduced TBS demand—but it did not change the main results. Only a "rather heroic" assumption of a long-term annual health benefit for DGT, consisting of prevention of hospitalizations of 3% over 20 years, renders a small net benefit to society.

4 Discussion

This paper applies a novel perspective to the market for CDT by analyzing these markets according to the economic theory of externalities. This allows analysis from a health system and societal perspective to guide policy makers in CDT regulation. The results suggests that in the Netherlands, CDT burden to the health system, leads to overconsumption from a societal perspective. However, the negative externalities are limited, requiring volume reductions of 3–19% to reach the social optimum, depending on the test. As a small percentage of consumers reports high consumption value of CDT, fully banning CDT is likely to harm social welfare. A lump sum—Pigouvian—taxation of CDT equal to the size of the externality would optimize social welfare, irrespective of current or future CDT prices. Other forms of discouragement may be easier for the government to enact. For example, TBS regulation currently pushes travel times as patients need to visit clinics abroad, thereby increasing private costs in a matter similar to a Pigouvian tax.

While our approach offers novel insights into evaluation of private CDT markets, some reservations apply. Willingness-to-pay measurements were only applied to specific variants of three CDTs. For other variants of these CDTs, or for other CDTs, other WTP valuations apply. Furthermore, consumers may overstate their willingness to pay for CDT in relation to actual consumption volumes. In our sample, actual consumption was estimated at 0.5% to 1.5%, while estimated consumption based on WTP was 1.1–3.3% at actual prices, or about double the actual reported consumption. A study using the same panel set-up estimated total CDT use (including other available CDTs) in the Netherlands at 5% in 2016 [51]. Although these authors do not differentiate between CDTs, their results could signal some underreporting of CDT use in our sample. Low numbers of (intended) users risks reporting bias. We estimated a demand function to correct for potential underreporting due to chance. While this risks overestimation of WTP if the demand function is misspecified, we found that the results are robust to alternative specifications and outlier trimming. Second, while we correct for differences in observable characteristics between the respondent sample and the general population, unobserved characteristics may affect response

rates. However, we did not find indications that CDT users were overrepresented in the respondent sample.

Regarding the follow-up costs, evidence was limited and of low quality, especially for commercial genetic health tests. Included studies had low sample size and limited time horizons, which risk excluding long-term cost-reducing effects of lifestyle changes and prevention. However, a number of studies show no effect on lifestyle changes or other clinically important end points following CDT [2, 4, 52–55]. Importantly, extrapolations of the findings in other settings to the Dutch situation may overestimate costs, as the highly accessible health system of the Netherlands likely biases latent prevalence downwards. Furthermore, Dutch GPs might be more reluctant to prescribe follow-up care after CDT [56]. Last, estimates of downstream effects depend on sensitivity and specificity of the tests. Incremental improvements in CDT performance over time are likely to improve benefits and reduce costs.

A randomized controlled trial would be preferred to assess follow-up costs, although this is often not feasible or is impractical in relation to CDT. In the absence of a control group, we have to assume that no additional health use would be observed in the absence of a CDT, which may be a strong assumption. Therefore, the reported effects may overestimate externalities. For example, in case of CCT we assume additional follow-up utilization during one year, after which the consumer returns to care as usual. For some patients, utilization would also increase in the absence of CCT, thereby overestimating the externality, while other patients may continue for years with undiagnosed high cholesterol in absence of a CCT, thereby underestimating follow-up cardiovascular risk-related utilization but also potential reductions in costs of complications. Additional research is required to improve estimates of follow-up use. Also, the characteristics of the CDT used to examine follow-up costs may deviate slightly from the CDT descriptions given in the WTP questionnaires in terms of number and types of tests performed as part of the CDT. This could reduce the accuracy of the estimates. For some CDT, such as DGT, additional positive externalities may be present; if heritable disease risk is present, this may positively affect the health of family members. This may not be fully reflected in the consumer's WTP, thereby potentially underestimating net benefits of CDT to society. This may also apply to COVID-19 antigen tests, which may exhibit positive externalities through reductions in virus spread due to quarantines after positive test results. In light of these limitations, our estimates should be seen as a first indication, potentially overestimating the societal costs of CDT.

To measure WTP, contingent valuation methods were applied. Contrary to existing CV literature, we explicitly test and account for common biases in CV methodology [22, 57, 58]. Furthermore, while most literature censors non-responses, our research explicitly considers that people may be unwilling to consume a CDT at any price including zero. Additional research could elicit a negative WTP for these persons, e.g., a willingness-to-accept (WTA) to have the test performed, to express that some persons may experience a negative utility of consumption. However, this may be beyond the interest of policy makers. Previous experience with CDT could have distorted the WTP values, also in light of product heterogeneity. Although this is limited in the Netherlands, and we correct for previous experience, some distortions in WTP in unknown directions may remain. Furthermore, simultaneous evaluation of three tests could affect valuations [59]. While we employ these simultaneous evaluations to correct for response biases, we cannot exclude the possibility that the order of evaluations, starting with CCT and ending with TBS, would affect WTP [60, 61]. Ideally, a larger sample size would allow random ordering of CDT evaluations and joint evaluation of WTPs, e.g., using seemingly unrelated regression techniques [59, 62].

Relative to the full sample, fewer respondents aged 18–39 completed the questionnaire. If a predominance of respondents with lower health completed the questionnaire, estimates could be biased upwards. We found no indication that sociodemographic differences between the respondents and the full sample biased the estimates, and different population weights rendered similar outcomes. However, a larger sample would improve accuracy of the estimates. While CDT is a complex intervention and a challenging topic for CV, we found few indications for comprehension bias, as the number of unfinished questionnaires was limited, response times were low, no bias was observed with respect to income and education, and no indications of incomprehension were found in the qualitative responses.

This paper finds that, compared to existing literature, a relatively large proportion of the sample (33–50%) was unwilling to consume a CDT even at a zero price. Furthermore, a large percentage of respondents were only willing to consume a CDT at zero costs. A study on PSA testing among middle-aged men in Japan found that 20% were unwilling to consume a PSA-test at a zero price. This figure was 22% in a US-based study on prevention of Alzheimer's disease [63]. The differences could be due to different tests being evaluated, although cultural differences could also play a role. The Netherlands is generally reserved with respect to medical consumption, while having a broad benefits package [64]. In accordance with the literature, this paper finds weak evidence of age, gender and income effects on WTP [63, 65, 66]. No effect of health status or previous experience was found, while some literature finds weak effects. Possibly, the effect of health status was too limited to be found significant given our sample size. It could also be the case that consumers with low health status are already in treatment, and

therefore have no need for CDT. This was a common theme in qualitative analysis, especially for CCT.

For policy makers, the results suggest that when CDT does not apply for collective financing, private consumption may still produce net welfare for society, despite additional follow-up costs to the health system. However, part of the additional burden to the health care system enhances total welfare, as consumption of CDT produces consumer surplus. For private consumption, non-health benefits, such as ease of mind, curiosity, experience, etc. should be taken into account (as well as non-health costs). While these effects are difficult to monetize individually, they are represented in an individual's WTP [9]. Therefore, the framework applied in this paper is more suited than traditional cost-effectiveness analysis to guide policy makers in whether regulation of CDT as a private market would be welfare-enhancing. One potential objection to CDT is that consumers often have difficulties correctly interpreting the outcomes, which could bias perception of value when purchasing a CDT, and thereby bias WTP. Especially in DGT, interpretability was a predominant theme in the open-field responses. These could be considered as internalities [67]. While internalities may be a concern for policy makers, this is not unique to CDT. Any goods or services that potentially exhibit internalities, e.g., gym memberships, casino visits, or alternative medicine, may benefit from additional regulation with respect to consumer education. In this, CDTs are no exception, and specific regulation beyond general consumer education regulation in this area may not be necessary. Furthermore, it is unclear whether the WTP increases or declines if consumers would be fully rational. For example, a 2006 study found no significant changes in WTP for PSA testing after consumer education [65]. Second, an argument could be made that private provision of CDT may increase inequality in health care use, as predominantly high incomes may consume CDT. This may be politically sensitive in a country with a broad solidarity in health use and financing such as the Netherlands. Current regulation dictates that collective access is provided for cost-effective care. In this aspect, CDT may be beneficial for selected, wealthy, individual consumers, but not for a group of (low-income) consumers. To avoid this public-private market paradox, policy makers may wish to limit access to CDT to preserve solidarity. Additional research into societal acceptance of high-income consumption of cost-ineffective care may be informative.

5 Conclusions

At current prices of three commercial diagnostic tests, it is estimated that 1%–3% of the population would purchase these tests. Commercial diagnostic tests carry follow-up health care expenditures that result in overuse from a societal perspective. This is largest for commercial cholesterol tests (18.9%), and smallest for TBS (2.5%). Due to the relatively low price and elastic demand of CCT, externalities are relatively high. However, the total burden of CCT to the health system is relatively low (€2.5–€7 million per year). So while externalities do exist, these are relatively limited under most sensitivity scenarios and may not require government intervention, especially for DGT and TBS. However, as the costs for these tests may decline in the future, inefficiencies increase and government scrutiny may be required.

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Code Availability All Stata codes and syntaxes are available upon reasonable request.

Declarations

Conflict of Interest None.

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

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