BioSocieties (2020) 15:601–626
https://doi.org/10.1057/s41292-019-00171-7

ORIGINAL ARTICLE

Imaginaries as infrastructures? The emergence of non-invasive prenatal testing in Austria

Ingrid Metzler[1]

Published online: 4 October 2019

Abstract Non-invasive prenatal testing (NIPT) is a new technology used in prenatal testing (PT) that capitalizes on genomic platforms to transform DNA fragments in the blood of pregnant women into information about the genome of a foetus. Since its market introduction in 2011, it has travelled around the globe with remarkable speed. This article engages with the emergence of NIPT in and around Vienna, the capital city of Austria, to explore why and how this technology could travel so quickly in practice. Based on a qualitative analysis of interviews, documents, and field notes, it argues, first, that NIPT could travel so quickly because it travelled as 'adaptable boxes' that added on to different 'local worlds of prenatal testing (PT)', without disrupting them. Second, in so doing, NIPT could travel on a moral and material ground, or an 'imaginary of PT', built in the past. Third, the article argues that elements of this imaginary were also mobilized by commercial pioneers of NIPT, who 'infrastructurized' extant values, practices, and networks among biomedical professionals. Thus, various actors converged in mobilizing moral and material elements of an imaginary, transforming them into an infrastructure that facilitated the travels of NIPT, while also shaping its use.

Keywords NIPT · Prenatal testing · Imaginaries · Infrastructures · Genomics

✉ Ingrid Metzler
ingrid.metzler@univie.ac.at

[1] Department of Science and Technology Studies, University of Vienna, Universitätsstraße 7/6, 1010 Vienna, Austria

Introduction

This article engages with the emergence of non-invasive prenatal testing (NIPT) for foetal aneuploidies, focusing on the region in and around Vienna, the capital city of Austria.

NIPT is a new practice in prenatal testing (PT). Unlike invasive procedures, such as amniocentesis or chorionic villus sampling (CVS), it does not require puncturing the pregnant woman's belly with a needle to access foetal DNA. Instead, NIPT capitalizes on the presence of cell-free foetal DNA (cffDNA) in the blood of pregnant women, where it circulates next to women's own cell-free DNA (cfDNA). A combination of genomic platforms and bioinformatics can transform the short fragments of DNA into information about quantifiable properties of the foetal genome, ranging from foetal trisomies, such as Down syndrome (trisomy 21), to sex-chromosome anomalies, and to micro-deletion syndromes.

NIPT began to emerge in 2011, when companies in California and China launched the first tests for foetal aneuploidies. Since then, NIPT has travelled with remarkable speed around the globe, becoming "the vanguard of genomic medicine" (Hui and Bianchi 2017). Yet, why? How could NIPT emerge and travel so quickly? This article seeks to begin to answer these questions by engaging with the emergence of NIPT in and around Vienna, the capital city of Austria, and parts of the surrounding regions of Lower Austria and the Burgenland.

In this region, the emergence of NIPT has been a fairly "subpolitical" (Vries 2007) phenomenon. So far, NIPT has not been rolled out in a top-down way across the Austrian territory as a whole. It emerged from below, when two public hospitals, dozens of private centres for PT and a few gynaecologists began to adopt NIPT, sending blood samples to commercial laboratories abroad. NIPT is not a widespread phenomenon in quantitative terms. In the words of a biomedical professional, it is "still a luxury test" (Interview 6/2018), as the cost is approximately 600 euros per test, which most women pay out of pocket or via private insurance. Moreover, the adoption of NIPT has also been regulated not via new provisions of national health care authorities but by the protocols of local providers and the recommendations of professional societies (Schmid et al. 2015a, b).

While the subpolitical nature of this case does not allow us to generalize findings to Austria as a whole, it can help us to get some clues on why and how NIPT could emerge and travel so quickly in practice. It allows us to shed some light on the enmeshing of the global, the national, and the local; the moral and the material (Löwy 2015, 2017); and new genomic tools and players and established technical devices and experts in the emergence and diffusion of NIPT (Gibbon et al. 2018, p. 3). More particularly, this case helps us to see that biomedical professionals adopting NIPT in 'local worlds of PT' in Vienna and actors envisioning NIPT in geographically more distant worlds converged in mobilizing extant values, practices, and materialities, transforming extant elements of an 'imaginary of PT' into an infrastructure that facilitated the emergence of NIPT.

I begin this article with a brief description of the global emergence of NIPT; situate this article within the body of literature that has engaged with NIPT in a

background section; and unpack the theory, methods, and concepts used in this study in a methodology section. The subsequent engagement with the emergence of NIPT in eastern Austria starts with a description of its context, discussing the history of the contemporary map of 'local worlds of PT' and arguing that these local worlds constitute the scaffolding of an 'imaginary of PT'. In the following sections, I explore how elements of that imaginary were mobilized—both in local worlds and in geographically more distant ones—when NIPT began to emerge. Describing the ways in which NIPT was used in local worlds in practice and analysing differences and similarities between these ways helps me to identify two puzzle pieces key to understanding how NIPT could spread so quickly. First focusing on differences in the adoption of NIPT, I argue that NIPT travelled as 'adaptable boxes' that were amenable to adoption in different worlds without disrupting the values and practices of those worlds. Second, exploring cross-cutting similarities, I argue that in all these worlds, NIPT was adopted as a 'new tool' (or 'add-on') for a previously agreed-upon 'job'—the early detection of foetal trisomies—and could thus travel upon the material and moral foundations of an extant imaginary of PT. Third, complementing the analysis of practices in the local worlds with a brief discussion of actions in geographically more distant worlds, I show that elements of this extant imaginary were not merely mobilized by local actors, but also harnessed by a commercial pioneer. Drawing together these puzzle pieces in the conclusions, I argue that the case of the emergence of NIPT in eastern Austria helps us to see that the mobilization of elements of an imaginary of PT built in the past, when by now "old technologies were [still] new" (Marvin 1990), transformed this imaginary into an infrastructure that facilitated the emergence and diffusion of NIPT.

Background

NIPT for foetal aneuploidy testing emerged when two recent advances in biomedicine began to intersect. In 1997, Dennis Lo and colleagues detected cffDNA in the blood of pregnant women (Lo et al. 1997). In 2008, two articles reported that a combination of next-generation sequencing technologies and bioinformatic calculations could help transform the short fragments of DNA into information about foetal aneuploidies (Chiu et al. 2008; Fan et al. 2008). Since 2011, a handful of companies in California (including Sequenom, Verinata, Ariosa, and Natera) as well as BGI in China have launched tests for the detection of foetal aneuploidies (Allyse et al. 2012). Over the past 5 years, other commercial players inside and outside of California and China have joined this race for shares in a "market in the making",[1] the scope and boundaries of which they helped to extend (Löwy 2017; Agarwal et al. 2013).

In a period spanning less than a decade, NIPT was transformed from a phenomenon located in China and California to an unevenly globalized technology that

[1] I borrow this expression from Stuart Hogarth and Paula Saukko's (2017) work on "direct-to-consumer genomics".

became ever more fluid as it spread geographically—in terms of the tinkering with the technical devices and algorithms involved in NIPT (Wong and Lo 2016), its envisioned users and imagined uses, and the sheer variety of values and actors that became entangled in NIPT as it was taken up in specific regions in practice. Initially, NIPT was envisioned as a riskless alternative to invasive procedures for the small group of women known to be at risk of carrying a foetus with trisomies (Allyse et al. 2012, p. 3123). However, subsequent reports on "discordant" (Grati et al. 2015; Mao et al. 2014) and "incidental findings" (Hui and Bianchi 2017, p. 464) demonstrated that NIPT could not replace invasive procedures and conventional karyotyping, which continued to be the 'diagnostic gold standard'. While NIPT was disentangled from *diagnosis*, it was re-envisioned as a tool for prenatal *screening*. Studies demonstrated that NIPT worked well in 'routine populations' of pregnant women, helping to re-envision NIPT as a screening tool for all pregnant women (Nicolaides et al. 2012; Fairbrother et al. 2013; Bianchi et al. 2014; Norton et al. 2015). At the same time, the scope of conditions that could be tested for expanded from foetal trisomies to sex-chromosome aneuploidies and 'microdeletion syndromes', which are characterized by the deletion of substantial sections of DNA (Wapner et al. 2015; Check Hayden 2014). Today, most providers offer a variety of versions of NIPT, which range from foetal aneuploidies to 'whole genome' NIPT (fieldnotes July 2018). Ever more actors and values became involved, as NIPT began to travel and to be adopted in specific regions around the globe. Commercial companies were exceptionally vociferous players in this process (Löwy 2017, p. 152; Ravitsky 2017, p. S36), but they were not alone. Their tinkering with the materiality and morality of NIPT was also shaped by professional societies (Dondorp et al. 2015; Benn et al. 2013; Salomon et al. 2017; Gregg et al. 2016), ethics councils (Nuffield Council on Bioethics 2017), state actors (Zeng et al. 2016; Karow 2018; Strange 2017) and civil society organizations (Braun and Könninger 2018), who puzzled over the ethical, social, and organizational issues of NIPT and suggested ways in which NIPT ought (not) to be used in practice.

A body of scholarly literature has addressed the ethical, legal, and social issues raised by NIPT and its expansion, dissemination, and increasing uptake (Haidar et al. 2016). While some scholars welcomed NIPT as a way to mitigate the problem of iatrogenic miscarriages, they also highlighted the tension between a further "routinization" of PT in light of the 'non-invasiveness' of NIPT and the requirements of genetic counselling to enable "informed choices" in practice (Lewis et al. 2017; Michie et al. 2016; Ravitsky 2017). Many raised the issue of the negative—and indeed potentially discriminatory (Kaposy 2018)—impact of the increasing salience of NIPT for conditions such as Down syndrome on individuals and groups living well with those conditions (Allyse et al. 2015; Michie and Allyse 2015; Parham et al. 2017). A growing part of this literature has used social science methods, such as surveys, to ground ethical reflections on the opinions and perspectives of women and health care professionals (Lewis et al. 2017; Strange 2017; Haidar et al. 2016; Ngan et al. 2017). Last but not least, scholars have also reviewed the "different meanings" of NIPT as it emerged in practice in the UK, Italy, China and Brazil, describing the ways in which this "technology is being integrated into the 'moral economy' of prenatal testing" (Zeng et al. 2016, p. 392). This latter work is related to Ilana Löwy's

enlightening unpacking of the history of the "prenatal diagnosis dispositif", which she shows to be a highly "heterogeneous assemblage of instruments and techniques, professional practices, and institutional and legal arrangements" (Löwy 2017, p. 2) "with many situated applications" (Löwy 2018, p. 14) and competing "moral economies" (Löwy 2015, p. 199). This article seeks to add to this latter type of engagement with NIPT and to follow Löwy's (2017, p. 190) invitation to study "the incorporation of norms and values into material practices" in specific situations in which PT is used.[2] Drawing inspiration from this work, the article engages with the ways in which NIPT was adopted in and around Vienna, and explores how the material and the moral were enmeshed in the situated emergence of this genomic technology.

Methodology

In terms of theory, I draw on a "technology in practice" approach (Timmermans and Buchbinder 2013, p. 10; Timmermans and Berg 2003, p. 104). This implies that I approach NIPT not as a universal object with a stable identity but as an assemblage of technical devices and the human beings who use them in practice (Barry 2001, p. 9). Such assemblages are always technical and material *and* social and normative, and always differently so in the specific situations in which these assemblages are put to work (Löwy 2017). Thus, when making sense of the specific case, I sought to understand how normative and material elements were enmeshed in the emergence of NIPT in and around Vienna. In doing so, I capitalized on the insight that early moments in the life of technologies allow us to disentangle the enmeshing of the material and the normative (Timmermans and Buchbinder 2013, p. 29). Indeed, in such moments, pioneers of technologies or "sociotechnical vanguards" (Hilgartner 2015, p. 34) build moral visions around technical devices to convince others to use them. Rephrasing the terms used by Monika Casper and Adele Clarke, actors need to convince others that a new device is the "right" or "good enough" (Paul 2016) tool for a particular "job" *and* that the "job" that the device helps to perform should also be done (Casper and Clarke 1998, p. 276).

In terms of materials, I base my argument on a selection of materials collected while following around NIPT to spaces in which it was adopted and adapted, endorsed or problematized, and regulated and governed. These included documents (such as newspaper articles, journal articles, patient information leaflets, and policy papers), fieldnotes from thirteen scientific meetings and public discussion events involving PT (in and outside of Austria) between March 2016 and July 2018, and 21

[2] In light of the smaller temporal and spatial scope of this case and a different focus of analysis, I describe 'local worlds of PT' and "imaginaries" rather than "moral economies" and "dispositifs". Yet, please note that "dispositifs" as used by Löwy (2017, 2018) building on Michel Foucault's work, and "imaginaries" do share a number of similarities. Both are heterogeneous assemblages, are always contingent and situated, and produce effects. I adopted "imaginaries" rather than "dispositifs", as I believe that "imaginaries" help to highlight the enabling and productive properties of such assemblages, while dispositifs tend, by now, to be associated with coercive and repressive powers (somehow ironically, given their Foucaultian background).

semi-structured interviews (Weiss 1995) conducted with biomedical professionals, policy-makers, and health care activists between March 2017 and July 2018.

When analysing these materials, I began with the spaces in which NIPT was adopted in practice. Loosely drawing on the work of Stefan Timmermans and Sara Shostak on "gene worlds", I approached these spaces as 'local worlds of PT', or as situated assemblages of technical devices used by biomedical professionals in practice, which are shaped by visions and values and constrained by "regulations and resources" (Timmermans and Shostak 2016, p. 35). In a first step, I explored how NIPT was adopted—and also "adapted" (Mol et al. 2010, p. 15)—in practice in these local worlds. However, agreeing that "[i]n practice, (…) [the local worlds] are deeply intertwined" (Timmermans and Shostak 2016, p. 36), I also sought to understand the relations between the local worlds of PT and their connections to other worlds, paying attention to cross-cutting values and practices, and to other worlds and actors repeatedly "implicated" (Clarke 2005, p. 46) in interviewees' accounts.

I found the notion of 'imaginaries of PT' helpful when thinking through the relations between these worlds, taking the specific assemblages of technical devices, values, practices and experts in the latter as specific enactments of broader "assemblages of materiality, meaning, and morality" (Jasanoff 2015, p. 4) built around and materialized in PT technologies. In doing so, I drew on the work of Sheila Jasanoff and colleagues on "sociotechnical imaginaries" (Jasanoff and Kim 2015; Jasanoff 2015; Felt 2015), adapting this concept to the properties of this case study. Jasanoff approaches imaginaries as "assemblages of materiality, meaning, and morality" (Jasanoff 2015, p. 4). She underlines that *imaginaries* are always "collective" (Jasanoff 2015, p. 6)—unlike the *visions* or "vanguard visions" (Hilgartner 2015) of individual pioneers. She emphasizes that while imaginaries are normative, encoding "shared understandings of good and evil" (Jasanoff 2015, p. 4), they must be thoroughly enmeshed in practices and routines, interwoven with institutions, and embedded with the materiality of technologies to amount to imaginaries. This implies that while imaginaries must be constantly re-enacted to gain stability and salience (Felt 2015; Jasanoff 2015, p. 5), once they gain some solidity, they are enabling and productive (cf. McNeil et al. 2017).

I built upon Jasanoff's understanding of imaginaries as "assemblages of materiality, meaning, and morality", adapting the concept to the properties of this case. Jasanoff (2015, p. 4) underlines that sociotechnical imaginaries "are not limited to nation-states (…) but can be articulated and propagated by other organized groups, such as corporations, social movements, and professional societies"; nonetheless, imaginaries at a national scale and state authorities as actors are nonetheless fairly prominent in empirical studies on sociotechnical imaginaries (cf. McNeil et al. 2017, p. 441). In the case at hand, state actors are not altogether absent, but they give way to a more dispersed patchwork of local biomedical professionals, epistemic networks, and commercial pioneers acting in geographically distant worlds. And yet, this did not make the imaginary of PT less powerful or less productive. In contrast, while fascinating case studies have discussed efforts to build infrastructures in order to transform specific visions of technological futures into imaginaries (Aarden 2017; Gardner and Webster 2017), in the case at hand, an imaginary of PT, built by a plethora of bricoleurs over a lengthy period in the past, became so solid and

powerful that it worked as "a new kind of infrastructure" (Felt 2017, p. 256) for the spread of NIPT—or one of "those systems, technologies, organizations, and built artefacts that do not need to be reconsidered at the start of a new venture" (Slota and Bowker 2017, p. 529).

But let me start by describing the history of the contemporary map of 'local worlds of PT' and the 'imaginary of PT' that these enact in the next section, before describing how NIPT was adopted in these worlds, and analysing how biomedical professionals acting in the local worlds and actors working in geographically more distant worlds converged in mobilizing elements of that extant imaginary in the following sections.

Contexting the case: on local worlds and an imaginary of PT

When NIPT began to emerge in eastern Austria in August 2012, it arrived on a complex map of local worlds involved in the provision of PT. These emerged at particular moments in time, materializing visions on what pregnancies were and how they—as well as pregnant women—ought to be taken care of in assemblages of technical devices, practices, values, and biomedical expert groups. In contemporary Vienna, these local worlds coexist, forming the scaffolding of a complex imaginary of PT.

Local worlds of PT

The foundations of today's map were laid by a set of top-down visions, which were enshrined into federal laws and implemented within the public health care system. In 1974, the Austrian parliament enacted a "Mother–Child-Pass" *(Mutter-Kind-Pass)*, a health prevention programme that entitles pregnant women (and eventually their children) to a number of examinations provided by gynaecologists (and pediatricians) in their offices for free (Anon 2014). The examinations during pregnancies involved the bodies of pregnant women and not the foetus. Since the programme's establishment, the list of examinations has been expanded several times, but PT was not included. Gynaecologists providing 'mother–child-pass-examinations' are actually discouraged from performing PT (unless they have certified qualifications). However, they must inform women about the existence of such tests (Kopetzki 2017).

PT in the form of a "scrutiny of the foetus" (Löwy 2017, p.3) began to take shape roughly a decade later. In 1981, the Austrian parliament added "prenatal diagnoses and cytogenetic examinations" to the list of social security benefits (cf. RIS 2007). A ministerial ordinance entitled carriers of genetic conditions, consanguineous couples, and pregnant women above the age of 35 to such services for free (Bundesministerium für Gesundheit und Umweltschutz 1981). These provisions were implemented in public hospitals across the national territory, where invasive procedures were provided by a first generation of prenatal diagnosticians to women above the

age of 35, and biopsied cells were analysed by geneticists in adjunct cytology laboratories (Wieser 2006).

After this first round of top-down visions imposed from the federal capital city of Vienna across the national territory, complementary visions of prenatal care began to emerge from below. Since the early 1990s, the agency shifted from federal state actors to local biomedical professionals, who inscribed epistemic, normative, and technical visions circulating in distant worlds abroad—and thus above the national scale—into local assemblages of practices, material devices, and expertise. As a consequence, local worlds of PT multiplied and practices began to diversify.

In the early 1990s, a group of obstetricians at a hospital in Vienna imported a then-brand-new vision of prenatal care from London (Schuchter et al. 2002). This vision began to profoundly transform PT in and around Vienna, extending the target group of PT from the small group of women above the age of 35 to all pregnant women while also multiplying and decentralizing the local worlds providing PT. At the centre of this new vision were ultrasound devices and a new group of experts in "foetal medicine", whose practical expertise in spotting and naming "unusual" or "strange things" (Interview 13/2017) helped to transform these technical devices into powerful technologies. This group originated around Kypros Nicolaides, the director of the "Harris Birthright Research Centre for Foetal Medicine" at King's College London. They found the "thickness" of the "nuchal translucency" (NT), a fluid collection in the neck of a foetus, to be associated with foetal trisomies, and they translated this insight into the suggestion that systematic NT measurements around the 12th week of gestation in all pregnancies could help to decide whether women should make use of an invasive procedure (Nicolaides et al. 1992; Snijders et al. 1998; cf. Löwy 2018, p. 12).

Importantly for the dissemination of this new vision of PT and—as I argue below—eventually also for the travails of NIPT three decades later, Nicolaides also built paths that allowed this new practice to travel well beyond King's College London.[3] He established the "Fetal Medicine Centre", a private clinic in London, and the "Fetal Medicine Foundation" (FMF), a registered charity in the United Kingdom. Based on an "avalanche of (…) numbers" (Hacking 1990) from measured foetuses, the FMF refined protocols, set standards for NT scans, and provided training and certificates to specialists from other nations—including numerous ones from Austria. Slowly yet steadily, London became a centre for research and a central node in an international network of a new group of experts in foetal medicine, with ties to many other regions in Europe—including eastern Austria. Many biomedical professionals from Austria were trained by the FMF before they worked in local worlds of PT in eastern Austria.

Since the early 1990s, protocols for NT measurements have been further developed and extended to other conditions (Kagan et al. 2006; Chitty et al. 2006). Today, NT measurements consist of measuring several ultrasound markers and—when

[3] This happened independently of the activities of state actors in some countries, such as Denmark (Schwennesen et al. 2010; Heinsen 2018) or the United Kingdom (Vassy et al. 2014), which included these ultrasound-based practices in national screening programs for foetal aneuploidies.

performed as a "combined test" (CT)—of the serum concentration of two hormones. All these values are then entered into a computer program that uses algorithms to "adjust" the general "background risk" (based on the pregnant woman's age of a pregnant woman) to "individual" or "patient-specific" risks for foetal trisomies 21, 18, and 13 (Nicolaides 2011; Kagan et al. 2008). The risk calculations are complemented by a systematic qualitative assessment of the foetal anatomy, which is referred to as "first-trimester screening" (FTS).

Over a period spanning slightly more than a decade, other public hospitals in and outside of Vienna followed the example of the pioneering hospital in Vienna, providing NT-measurements, CTs, FTS, and/or "organ screening" (OS)—that is, systematic assessments of the foetal anatomy around the 20th week of pregnancy—to women registered to give birth at these hospitals. However, over the last decade, such services have been cut down. Today, three (out of nine) hospitals (with obstetrics departments) in Vienna continue to provide FTS for free. The other six public obstetrics departments in Vienna and the 21 in the neighbouring regions do no longer provide FTS for free.

Today, NTs, CTs and FTS are provided predominantly in private PT centres, where women cover the costs of FTS from their own pocket or via private insurance. These centres began to emerge at the turn of the century and have contributed to the routinization of NTs, CTs, and FTS, while also configuring these practices as a special form of PT that should only be provided by certified experts with appropriate training in foetal medicine. All providers of PT are either certified by the "Austrian Society for Ultrasound in Medicine", the FMF, or both, in order to demonstrate that they can perform such tests *lege artis*.

An imaginary of PT

Thus, a multiplicity of public and private local worlds are involved in the provision of PT in contemporary Vienna. All of them emerged at particular moments in time, materializing visions of prenatal care into assemblages of technical devices, practices, and types of expertise. Today, they constitute the heterogeneous scaffolding of an 'imaginary of PT', which is enacted differently in these local worlds without falling apart.

In this imaginary, PT can generate information, which, drawing on words frequently used by biomedical professionals, can be a "life-saver" for foetuses with heart defects to help to "avoid surprises at birth", or to provide prognostic reasons for the interruption of pregnancies. In this imaginary, (not) parenting a child with Down syndrome or other syndromes or disabilities is a contested and difficult yet, drawing on another frequently used wording, always "deeply personal" choice (*eine zutiefst persönliche Entscheidung*). Some women, those over the age of 35, are actually entitled to access such information in the public health care system, following criteria that were fairly literally 'set in stone' in 1981. Moreover, gynaecologists providing 'mother–child-pass examinations' must inform all other women about PT (in order to avoid lawsuits). However, if women wish to have access to prenatal testing,

they need to exercise this 'right to information' as consumers in the private worlds of PT.

This fairly complex imaginary is not only the effect of actions in the local worlds providing PT. It was stabilized, too, by many, even if admittedly not all, pregnant women in the urban areas in and around Vienna, who conduct PT as a 'routine'—or as a "normalized part" (Wahlberg and Gammeltoft 2018, p. 14) of being pregnant. It was also fine-tuned by high court decisions that have condemned gynaecologists for not informing women about the possibilities of prenatal testing or for not having performed them *lege artis* (Kopetzki 2017). Groups that articulated alternative visions of what pregnancies are and how they ought to be lived often built their own worlds of counselling around those visions, contesting the "medicalization" of pregnancy (Interview 8/2017). Disability rights groups, which criticized the "dragnet" on Down syndrome (Hager 2013), and fairly vocal pro-life groups that question the legitimacy of interrupting pregnancies, also contributed to the complex shape of this imaginary (Griessler and Hadolt 2006).

In light of the plurality of its bricoleurs, the imaginary of PT that ties together the local worlds of PT is not without frictions or contradictions. Arguably, it actually gains some of its salience through its power to make those contradictions invisible and through its ability to transform the controversial questions of how collectives should address prenatal technologies, motherhood, disabilities, and unborn life into the dispersed personal choices of women.[4] When NIPT begun to emerge in Vienna, this imaginary of PT was not opened up. Instead, NIPT travelled along the moral and material grounds of this imaginary.

The emergence of NIPT in and around Vienna

NIPT began to emerge in Vienna when biomedical professionals in several of these local worlds began to adopt such tests. In August 2012, a local hospital began to offer the Praenatest commercialized by LifeCodexx (Konstanz, Germany). The following year, another one introduced the Harmony test from Ariosa Diagnostics (San Jose, USA). Simultaneously, all private centres providing PT, as well as a few obstetricians, began to offer NIPT to pregnant women using tests from different providers. Today, a few centres offer the Praenatest, the Panorama test (Natera, USA), the Fetalis test (Amedes, Germany), and the NIFTY test (BGI, China). However, even in the absence of exact numbers in the fluid field of NIPT, it seems fair to claim that the overwhelming majority choose to offer the Harmony test, either via Ariosa's central lab in San Jose or via its 'German branch' Cenata in Tübingen (Germany).

When NIPT began to emerge in Vienna, the local worlds of PT were tied to commercial laboratories located abroad. In practice, NIPT arrives to local worlds as 'paper boxes' containing paper forms to complete, blood tubes, and transport

[4] This is not unique to Austria. See Löwy (2017, pp. 8–9) and Ravitsky (2017) for a discussion on how "the 'choice' discourse" (Löwy 2017, p. 8) as well as a focus on "autonomy" (Ravitsky 2017) single out women, while silencing the structured situations in which women make choices, in other contexts.

materials. Biomedical professionals inform women about the details and limits of this test, complete the paperwork, take blood samples, and use courier services to send them to one of the commercial laboratories located in Germany, Slovakia, the United States, or China. There, several dozens of samples are processed at once, rendering the use of genomic platforms reasonably cheap and, as one of my informants insisted, the "handling" of samples also "good" and "flawless" enough to ensure reliable test results (Interview 5/2017). Test results are returned via a server, fax, or postal mail to local biomedical professionals, who communicate the test results to pregnant women. Between 3 days and 2 weeks elapse between the collection of the blood samples and the return of the test results.

Thus, with the emergence of NIPT, a new layer of geographically more distant worlds was added to the map of local worlds providing PT. I briefly return to one of these more distant worlds at the end of the analytical part of this article. However, before I zoom in on some of the local worlds of PT, describing how biomedical professionals adopted NIPT in practice and discussing how elements of the extant imaginary of PT shaped the local adoption of NIPT in practice.

The adoption of NIPT in local worlds of PT

NIPT in public worlds

NIPT was adopted in two of the three public hospitals in Vienna, which, respectively, offer PT to all or half of the "collective" of approximately 2500 women registered to give birth in each of these hospitals every year.

At both hospitals specializing in PT and prenatal diagnosis, NIPT seemed to be a "must have", or, in the words of an interviewee: "[I]f [we] offer prenatal diagnostics free of charge here—for those we register for birth—then there is no point in not offering NIPT" (Interview 10/2017). He then continued:

> Previously, if the first-trimester screening text was unsatisfactory, it was said, well, if we really wanted to know exactly, we'd have to take a needle and stab it into the mother's belly—to take villi or amniotic fluid to clear it. Now, of course, this non-invasive prenatal diagnosis is a huge advantage because [it] saves the risk of the puncture. (Interview 10/2017)

The "non-invasive" nature of NIPT was often highlighted as an obvious benefit. However, its integration into the services offered in these public worlds was often less clear. In interviews, this integration was attributed to the personal "merit[s]" (Interview 4/2017) of single actors, who managed to convince hospital managers to allocate resources for NIPT—against the odds of the resource constraints shaping the provision of PT in these public worlds.

A need to distribute scarce resources also shaped how NIPT was adopted in practice in these hospitals. Both hospitals had a protocol, or a "script" (Akrich 1992), that standardized the adoption of NIPT, which was used as a contingent test in a "two-stage screening" (Interview 13/2017). Women had to fulfil certain criteria to "fall into the group of the women, who get this for free" (Interview 7/2018). They

had to be part of the collective of women registered to give birth in the hospital. Moreover, they also had to be part of an "intermediary risk group". The extant practice of FTS, which continued to be an 'obligatory passage point' for all women who agreed to PT, helped at once to stratify pregnant women and to allocate scarce resources.

FTS helped to categorize pregnant women into three groups. A first group of "high-risk pregnancies" continued to be referred for invasive procedures. This group consisted of "cases" whose FTS showed foetal anatomical anomalies, markers associated with heart defects, "significantly increased" NT (larger than 3.5), or whose calculated risk for trisomies was larger than 1:50 or 1:100 (the two hospitals used different "cut-offs"). Some informants noted that the comparably high "adjusted risk" in this group justified the risk of side effects from invasive procedures (Interview 5/2017). Many emphasized that invasive procedures were medically more reasonable for these women, as they could help to "answer a much bigger spectrum of questions" (Interview 7/2018). Significantly increased NTs and visible anatomical anomalies were associated not only with foetal trisomies but also with phenomena such as "micro-deletion syndromes", which are characterized by the loss of large chunks of DNA. Invasive procedures, biomedical professionals explained, allowed the retrieval of cells that could eventually be analysed with the help of microarrays in nearby laboratories if conventional karyotyping did not produce findings.[5]

A new second group consisted of pregnant women in a "middle or intermediary risk range" (Interview 7/2018) for trisomies. In both hospitals, these were women without visible foetal anomalies in FTS and whose calculated risk of trisomies was between 1:50 or 1:100 and 1:1000. Both hospitals offered NIPT for the three major trisomies free of charge to this group of women. This approach helped to avoid invasive procedures while still increasing the detection rate of trisomies and reducing ambiguities from risk calculations. Finally, a third group of women was referred for "organ screening" at a later stage of pregnancy.

NIPT in private worlds

While in public worlds NIPT was the exception, in private worlds it was the norm. The private centres are heterogeneous and differ in size, in the technical devices they have in place, and in the scope of testing offered. However, they share one common element that sets them apart from public hospitals: they do not provide PT free of charge. Women and couples pay out of pocket or via private insurances. Hence, in these private centres, some of the resource constraints shaping practices in hospitals are outsourced to women and couples. This made a difference in how NIPT was adopted in practice.

In the private centres, NIPT was adopted in two ways. First, women could choose NIPT as a "primary screening test" before—and thus independent from the results

[5] Microarrays compare the genome of a foetus with a reference genome printed on a chip, helping to visualize microdeletions. See Löwy (2018, pp. 97–104) for a discussion of microarrays and Turrini (2014) for debates on microarrays in Italy.

of—FTS. Seemingly depending on whether the centres were located in more or less wealthy districts of Vienna, biomedical professionals reported that anywhere from "very few" to 80% of women chose NIPT as a primary test. Blood samples were taken in the tenth week of pregnancy in combination with a "quick ultrasound". Test results were emailed to patients, communicated via telephone, or discussed 2 weeks later in combination with a detailed first-trimester anatomy scan.

Second, NIPT was also adopted as a "secondary" test after an FTS. One practitioner deemed such a "contingent" use reasonable for most pregnant women, in light of FTS sometimes revealing "conspicuous things" that would, in hindsight, render an already-performed NIPT as "money down the drain" (Interview 1/2018). Another interviewee emphasized that he preferred this option, as this avoided the "wrong impression" that an NIPT could replace FTS altogether (Interview 5/2017). Indeed, all my informants agreed that FTS helped to sort out a small group of "high-risk pregnancies" for whom NIPT was medically unreasonable and "not enough" or "a little too little" (Interview 2/2018).

Hence, as in the case of the hospital, cfDNA testing was deemed appropriate not for "high-risk pregnancies" but for a group deemed at an "intermediary" risk or in a "grey area" (Interview 2/2018) after FTS. However, in these private worlds, membership in this "intermediary risk group" was not predefined by "cut-offs", as it was in public hospitals. Decisions on when to perform an NIPT after an FTS emerged in situ in light of women's own expectations and understanding of "risks" or "probabilities". A biomedical professional explained to me that risk numbers as "cut-offs" would not make sense on an "individual basis", explaining

> We give them some guidance, on what most others would do, or what we would recommend, and we also always mention the guideline of the [Austrian Society of Ultrasound in Medicine] (….) However, we leave open all options (…) Because it is really a very individual decision. (Interview 7/2017)

Biomedical professionals running these centres had different understandings of women's decisions and their reasonability. However, they converged in their understanding that it was their job to inform women about available test options and to perform such tests *lege artis*, while it was the job—and indeed, the "right" (Interview 1/2018)—of women to choose what they wished to know.

This 'right to information', however, had some limits. Some women and couples reportedly chose NIPT to learn about the sex of a foetus for recreational purposes: in the words of an interviewee, "[u]nfortunately, we also have a few who do a NIPT test just because they want to know the sex". When I asked why this was "unfortunate", I was offered this explanation: 'Well, because they, if the right sex is not there, they can still interrupt [the pregnancy] within the first-trimester-regulation' (Interview 2/2018). Approximately a quarter of my informants reported anecdotal experiences with requests for NIPT that they deemed to be tied to the wish to "abort the wrong sex" (Interview 10/2017); those requests were denied.

Moreover, biomedical professionals were also not convinced of the appropriateness of extending the scope of NIPT from trisomies to sex-chromosome aneuploidies or microdeletion syndromes, which many test providers offered. A biomedical professional explained the following:

> We have decided from the beginning not to mention this, because most of them are in any way not serious, because there are many false-positive results, quite a few, and most of them are so harmless that you would not in any way have an interruption of a pregnancy as a consequence. Therefore, we have decided, well, if somebody wants it, then we cross [the box on the form], but we do not actively counsel for it, because this is way too complex for, well, and it is of no use. (Interview 7/2017)

Echoing concerns about the rash market release of such test options, another biomedical professional told me that he would not perform such tests, even upon request, because these were "validated too badly" (Interview 1/2018).

Interestingly, many of my interviewees also referred to "good data" to explain why they had chosen to work with a particular test provider (very often the Harmony test from Ariosa). One of my informants noted that she began to use the Harmony test after the completion, in December 2012, of a major study conducted by Ariosa in collaboration with the FMF, noting that "they then had by far the best data, they still do" (Interview 7/2017). She also referred to the Ariosa group as "smart and dynamic", noting that "this simply convinced me that they, that you can trust them, because, a lot depends from it, doesn't it? (Interview 7/2017). This view was echoed in other interviews, in which I was told that research conducted by the FMF had an important role in choosing this test provider, or, in the words of another interviewee: "And that means, that you have to honestly say, this is, they are, they really have high quality standards" (Interview 2/2018).

In addition to the "good data" and "high quality" that made a test provider trustworthy, several interviewees also emphasized that this test was "convenient" (*praktisch)* for them, referring to courier services or a colleague who collected blood samples. Thus, using a term developed by Michel Callon and colleagues, biomedical professionals choose the test provider they felt they could "punctualise" (Callon 1990, p. 153). In light of the wealth of data that proved the quality of these tests, they did not have to bother with the complex assemblages of professionals, practices, material devices, or algorithms used in some distant commercial worlds. They could "black box" (Callon and Latour 1981) these complexities, using these distant worlds as reliable infrastructures for their own practices. For biomedical professionals adopting NIPT in and around Vienna, NIPT was an exchange of a woman's blood sample for a reliable test result.

Differences and similarities in local worlds of PT

How does this description of how NIPT was adopted in the local worlds of PT in and around Vienna help us to understand how and why NIPT could travel so quickly? In this section, I distil two puzzle pieces from the description in the last section, first focusing on differences between these worlds and then discussing the commonalities between them, before briefly unpacking some of the actions in geographically more distant worlds to complement the two puzzle pieces from the local worlds with a third.

NIPT as 'adaptable boxes'

NIPT was adopted differently in the public and private worlds that provide PT due to the different resources, values, and practices assembled in those worlds. In the public worlds of 'doable PT' shaped by limited resources, NIPT was adopted with one protocol or "script" (Akrich 1992). This adoption stabilized it as a "secondary test" for a well-defined subgroup of women who, after an FTS, were deemed to be at an "intermediary risk" of having a child with a trisomy. The adoption of NIPT in the private worlds of "personalized"[6] or 'customized PT' was more flexible and shaped by the wishes and voices of women consuming NIPT in these worlds. Women could choose NIPT either as a "secondary" test if *they* deemed risk numbers from FTS problematic or as a "primary" test before an FTS.

These differences provide us with a first puzzle piece that helps us understand how NIPT could travel so quickly in practice. NIPT arrived at these different worlds in the same paper boxes from commercial laboratories. However, the boxes did not prescribe when and for which purposes they would be opened. These decisions were left to local users and thus to biomedical professionals and/or women. Loosely building on insights from science and technology studies on how technologies travel, the boxes did not enforce a singular "script" (Akrich 1992) or moral vision of how NIPT ought to be used. These were 'adaptable boxes' that arrived with a variety of moral possibilities, which could be "adapted" to the specific assemblages of values, practices, and resources available in local worlds (Mol et al. 2010; Law and Mol 2001).

An add-on travelling on an extant imaginary

That NIPT was flexible enough to travel to different worlds provides us with one piece that can help us understand the puzzle of how NIPT could travel so quickly in practice. Exploring cross-cutting similarities provides us with another piece.

Before discussing the substance of the similarities in more detail, a short note on the recommendations of professional societies is helpful to understand the salience of these similarities. In April 2015, four Austrian professional societies published recommendations on the use of "non-invasive prenatal tests (NIPT) for the analysis of cell-free DNA (cfDNA) in maternal blood" (Schmid et al. 2015a). Shortly afterwards, biomedical professionals from Germany and Switzerland joined their Austrian peers and published a slightly amended version: "Austrian-German-Swiss Recommendations for non-invasive prenatal tests (NIPT)" (Schmid et al. 2015b). Both documents endorsed NIPT for Down syndrome screening, envisioning scripts for its adoption as "secondary screening" or as "primary screening" (Schmid et al. 2015a, p. 7, b, p. 509), and they problematized the extension of NIPT to sex-chromosome aneuploidies and microdeletion syndromes (Schmid et al. 2015b, p. 509). The recommendations were both a cause and an effect: they built on shared values, recommendations from other professional societies, and data from studies. Enshrining

[6] I borrow this term from Mianna Meskus' (2012) work on PT in Finland.

understandings of how NIPT ought to be adopted in practice, they also prescribed those understandings for others—if only through the 'soft governance' tool of recommendations. Thus, the recommendations were shaped by an imaginary of PT, while they also re-enacted that imaginary, helping to govern and regulate NIPT from below.

By way of substance, first, in all these local worlds, NIPT was endorsed as an 'add-on' to the assemblages of extant practices, technical devices, and the expertise of biomedical professionals that helped to improve them without making them meaningless. NIPT reduced the number of invasive procedures, increased the proportion of actual findings, and decreased the proportion of those invasive procedures that turned out to be "unnecessary". However, NIPT did not eliminate invasive procedures altogether. While the NIPT results were deemed robust enough to exclude trisomies, the results indicating the presence of trisomies needed to be confirmed with invasive procedures (Schmid et al. 2015a, p. 5). Invasive procedures also gained a new importance for the new group of "high-risk pregnancies"— conspicuous "foetotypes", for whom invasive procedures and micro-arrays emerged as a new standard of care.

NIPT was also not considered to make the ultrasound obsolete. The recommendations enshrined that "cfDNA tests should only be offered after or in connection with a qualified ultrasound scan" (Schmid et al. 2015a, p.4). An informant involved in wording those recommendations explained that putting this on record was important so as "to avoid that pregnant women end up buying a test somewhere in a pharmacy and believe, all set, that this covers everything that exists" (Interview 1/2018). That NIPT could not supplant examinations with an ultrasound was also often underlined in scientific meetings and in interviews. Experts insisted that FTS was "not only about Down syndrome" (Interview 6/2018) but also about a range of foetal anomalies that examinations with ultrasound could detect.

Second, NIPT was adopted and endorsed as an 'add-on' for the performance of a particular job: the production of information about foetal trisomies in general and about Down syndrome in particular. The recommendations drew on data about the performance of NIPT tests to substantiate that NIPT did a better job detecting instances of Down syndrome (or, in their vernacular, had a better "sensitivity") while it also produced fewer false positives (or had a higher "specificity") than extant screening practices (Schmid et al. 2015a, p. 7). However, the recommendations did not raise the more principal question of whether common foetal trisomies *should* be screened for at all. Apparently, they took the answer to this question for granted—in light of an extant 'imaginary of PT' carved out when FTS began to extend testing for foetal trisomies from a subgroup of women to the entire population of pregnant women.

The importance of this imaginary for the travails of NIPT becomes clearer when we look at a third cross-cutting similarity, that is, the problematizations of those other 'jobs' that NIPT promised—or threatened—to perform, which were new and outside of the boundaries of the previously agreed upon imaginary. Some biomedical professionals were concerned about couples potentially using, or abusing, NIPT to learn the sex of a foetus to interrupt a pregnancy if it was the unwanted sex. Moreover, all my informants reported being sceptical about commercial providers of

NIPT extending the scope of NIPT to sex-chromosome anomalies and micro-deletion syndromes, articulating concerns that were also enshrined in the recommendations of professional societies.[7] These drew on the very same metrical values used to endorse NIPT for Down syndrome screening to problematize its extension to other chromosomal and subchromosomal syndromes, noting that data on the performance of NIPT for these conditions was not robust enough for these tests to be "recommended without restrictions" (Schmid et al. 2015a, p. 8, b, p. 509). Thus, neither was NIPT deemed robust enough as a tool for the screening for microdeletions and sex-chromosome anomalies in the general population, nor was there a consensus that this was a job that ought to be done.

Condensing the three similarities cutting across the local worlds helps us add a second piece to the puzzle of how NIPT could travel so quickly. NIPT was adopted as an add-on to extant assemblages that helped improve the production of information about foetal trisomies at an early stage of pregnancy in all local worlds of PT—even if it was adapted more or less flexibly and with different frequencies. Thus, pioneers seeking to disseminate NIPT did not need to venture into the arduous work of convincing others of the desirability of the job that this device helped to perform. They could take the moral ground for granted, harnessing *moral* elements of an extant imaginary. NIPT was used as a *new* tool for an *old* job. Because NIPT was adopted as an 'add-on' that did make existing practices, technical devices, and biomedical experts meaningless, it could also travel in and through those worlds initially created to accomplish this job, adding on to them without disrupting them, and thus also harness *material* elements of the extant imaginary of PT.

An instance of the past explaining the present?

The emergence of cfDNA testing in and around Vienna thus appears to be a case in which an emerging technology could travel exceedingly well, as it could capitalize on paths 'trodden' by pioneers of earlier PT technologies in the past, travelling in and through the moral and material grounds of an extant imaginary of PT while also reifying it. Drawing loosely on Peter Keating and Alberto Cambrosio's succinct terms, this case—or, actually, my account of it—seems to be a(nother) case in which the "past (…) explain[s] the present" (Keating and Cambrosio 2012, p. 10). And this might also be its problem: It "explains too much" (Prainsack 2006, p. 189). It helps us to see *that* extant biomedical professionals, local worlds, and imaginaries helped to 'smooth' the emergence of NIPT while also limiting its scope; but it does not explain *why* these extant realities were so powerful or *how* all these extant realities begun to matter.

In order to improve our understanding of the salience of these extant realities, I wish to briefly unpack one of those geographically more distant worlds that local biomedical professionals repeatedly implicated in their accounts. In the next section,

[7] I do not claim that such tests are not available. They are not widespread, but they are offered. However, biomedical professionals offering these tests move on the thin ice of a "vanguard vision" (Hilgartner 2015).

I explore some steps in the making of the "Harmony test", the apparent market leader in and around Vienna. I do not provide a comprehensive picture of the development of the Harmony test, which was originally developed by Ariosa Diagnostics (San Jose, CA), a company now owned by Roche Diagnostics (Roche 2014). I focus on only those actions that proved—or happened to produce—effects in the local worlds of PT in eastern Austria, so as to add a third piece to the puzzle of how NIPT could travel so quickly in practice.

A puzzle piece from elsewhere

When Ariosa launched the Harmony test in May 2012, it took a number of steps that continue to resonate in contemporary Vienna.

First, early on, Ariosa seems to have envisioned the Harmony test as a trisomy screening test for the general population of pregnant women (cf. Chitty et al. 2012, p. 270). Ariosa also inscribed this vision into the material design of its test. The company did not rely on "indiscriminate" (Sparks et al. 2012, p. 319.e1) sequencing of all cfDNA fragments first and sorting via algorithms later (as other commercial test providers did). It developed an assay to preselect DNA from the "chromosomes of interest" (Sparks et al. 2012), focusing subsequent sequencing on the preselected fragments. This approach enabled reducing the amount of sequencing needed per sample, increasing the number of samples sequenced at once and reducing the costs of the test.

Second, Ariosa also invested time and resources into large studies, publishing them in prestigious peer-reviewed journals. Commenting on one such study, Ariosa's CEO Ken Song declared that it "affirms our commitment to leading the introduction of NIPT into medical practice based on robust clinical data" (Ariosa Diagnostics 2012). Thus, early on, the commercial company began to produce the kind of arguments that biomedical professionals in Vienna—and thus miles away from Ariosa's headquarter in California—eventually found so convincing: data and evidence. Like Steve Epstein's '"lay expert" activists' (Epstein 1995, p. 429) in the field of HIV and AIDS in the 1990s, the company made an effort to "present themselves as credible *within* the arena of credential expertise" (Epstein 1995, p. 409) by learning and speaking the language of experts in foetal medicine, producing evidence and data, and publishing these data in prestigious journals.

Third, another important step taken by Ariosa was that a number of these studies were conducted in collaboration with Kypros Nicolaides and the FMF (Ashoor et al. 2012; GenomeWeb 2012b; Nicolaides et al. 2012; Norton et al. 2015)—and thus with a central expert in the field of prenatal testing. As discussed before, Nicolaides had helped to pioneer the transition from PT in the form of invasive procedures for predefined subgroups to FTS for the entire population of pregnant women from the early 1990s on, building a transnational professional network around a research and training hub in London. This approach had helped this then-new vision expand to worlds outside of London—including to local worlds of PT in and around Vienna. The FMF was not the only site with which Ariosa collaborated, nor was the Harmony test the only test evaluated by the FMF. However, from October 2012, Ariosa

also partnered with the Fetal Medicine Centre in London, which offered the Harmony test in the UK (GenomeWeb 2012a). By managing to win Nicolaides as a 'spokesperson' for the Harmony test, Ariosa obtained access to the British market *and*—as my interviews with local biomedical professionals in the east of Austria suggest—also to some of the local worlds tied to the epistemic network around him, including those located in and around the city of Vienna.

This brief excursion to worlds outside of Austria helps me to add a third puzzle piece, which complements the other ones. It helps us to see that the salience of extant moral and material elements in the local worlds in Vienna described before was not merely the reason for the quick emergence of NIPT; their salience was also an effect of actions taken by at least one commercial player. Rather than venturing into building a radically new vision of prenatal care around its new technical device and assembling new practices, experts, worlds, or building entirely new infrastructures, Ariosa mobilized extant moralities, practices, experts, and worlds, transforming them into an infrastructure that helped to make its innovation travel. Thus, just as biomedical professionals in and around Vienna felt that they could "punctualize" the Harmony test, "blackboxing" the machineries, algorithms and people assembled in Ariosa's lab into a reliable infrastructure they could trust, so Ariosa "punctualized" an international network of biomedical practitioners, by convincing a central figure in this network of the merits of the Harmony test, and by "blackboxing" the practice, values, and experts that this network had helped to pioneer in the past. The extant imaginary of PT, built over lengthy years in the past, became so powerful and productive in the case of the emergence of NIPT, as both local actors in Vienna *and* actors in more distant worlds converged in harnessing and re-enacting elements of it. They "blackboxed" moral and material accomplishments of the past, transforming elements of an extant imaginary of PT into an infrastructure that facilitated the travails of NIPT.

Conclusions

This article engaged with the emergence of NIPT in and around Vienna, using this case to begin to understand how NIPT could emerge so quickly and travel so far in practice. It is built on a description of how NIPT was adopted in local worlds of PT in the east of Austria and a brief exploration of actions taken in geographically more remote worlds by a commercial pioneer that happened to produce effects in Vienna to discuss three complementary puzzle pieces.

The article situated the emergence of NIPT on a map of local worlds of PT, which emerged at particular moments in time and materialized particular visions of PT into assemblages of technical devices, practices, and expertise. It conceptualized these local worlds as the scaffolding of an imaginary of PT, which is enacted differently in these worlds, without falling apart. Subsequently, the article showed how moral and material elements of this imaginary were harnessed by local biomedical professionals and commercial pioneers acting in geographically more distant words and how these dispersed actions converged in transforming elements of the imaginary of PT into an infrastructure that facilitated the travails of NIPT.

More in particular, I argued, first, that NIPT travelled in the form of 'adaptable boxes'. While these boxes connected the local worlds in Vienna with laboratories abroad, they did not prescribe when and for which purpose they ought to be opened up. They were flexible enough to be adapted differently in the local worlds of 'doable PT' in public hospitals, where they were used as "secondary screening" tools, and in the worlds of 'customized PT' in private centres, where they were used as "secondary" and "primary screening" tools. Second, while NIPT was adapted slightly differently and with different frequencies, it was used as a new technical device for the production of information about foetal trisomies at an early stage of pregnancy in all these local worlds and thus as a new tool for a previously agreed-upon job. Hence, I argued that NIPT travelled on a moral and material ground—or 'imaginary of PT'—paved by a plethora of pioneers across a lengthy period in the past, adding on to this ground, without undoing it. Third, I have also briefly visited actions taken in geographically more distant worlds to show that the salience of this extant moral and material ground was also the effect of work done by at least one commercial pioneer of NIPT. Rather than venturing into envisioning a new "vanguard vision" (Hilgartner 2015), this company fine-tuned the materiality of its test to make it fit into established visions and practices of PT. It also invested time and resources into the production of data that helped to convince biomedical professionals that its test produced reliable results. Among these professionals was an expert, who had helped to pioneer FTS in the past, spearheading the building of an international network of experts in foetal medicine around a research hub in London. In this way, the company also obtained access to a variety of experts tied to the same professional network and to some of the dispersed local worlds that this network connects.

Drawing together the three complementary puzzle pieces helps us to understand how NIPT could emerge so quickly in and around Vienna. It helps us to see that the fairly smooth emergence of NIPT in and around Vienna was an instance in which moral and material elements of an imaginary of PT, built when (now) "old technologies were [still] new"(Marvin 1990) in the past, were re-enacted by actors in local and more distant worlds alike. They were mobilized by a company that infrastructurized extant values, practices, experts, and the networks between them *and* by local biomedical professionals who adopted and endorsed this new technical device as an add-on that helped them provide better FTS to pregnant women. Thus, rather than one of them being the reason and the other ones its effects, the puzzle pieces complement each other. Local biomedical professionals and global stakeholders converged in transforming elements of an extant imaginary into an infrastructure. They blackboxed moral and material accomplishments of the past, transforming elements of an extant imaginary of PT into an infrastructure that enabled and directed the emergence of NIPT, speeding up the travails of NIPT while also shaping its use.

Before thinking through what to take away from this specific case, some words on its specificities and the limitations of this study are needed. In the case discussed in this article, NIPT travelled by adding on to a fairly dense web of local worlds of PT built around ultrasound devices, and by transforming past accomplishments into infrastructures. While similar dynamics might be at work in other regions in Europe, where ultrasound-based FTS is by now routine for many women, there are other regions in the world where such local worlds to which NIPT can be added on are

rare or non-existent and where NIPT might spread in different ways, at a different pace, or not at all. Moreover, while I have singled out the company that developed the market-leading test in the region discussed in this article, this is definitely not the only commercial player in the fiercely competitive and very fluid global assemblage of NIPT. Other commercial players might well pursue different visions. It would be fascinating to compare the different ways in which companies tinker with the materiality of genomic machineries and the boundaries of moralities while they seek to get their innovations off the ground, exploring when and how they seek to add-on to existing moral and material realities, when they venture into building imaginaries and infrastructures on their own, or when and how they do both at once. Last but not least, the emergence and travails of NIPT might also differ in those regions where state actors assumed a more central role in the ordering of NIPT and/or establishing FTS in the past than they did (so far) in Austria, just as the travails of NIPT might change in Austria if, say, public health actors decided to take a more central role in the future.

Thus, it would be rash to generalize the findings on how the global and the local, the moral and the material, and the old and the new converged in the emergence of NIPT in this specific region to other regions. Nonetheless, this case can sensitize us to the complex interplay between the extant moral and material worlds of PT in particular and genomic technologies in general and the emerging new worlds that venture into unleashing their power. It can draw our attention to how commercial pioneers might, at times, mobilize extant practices and moralities to establish their place in routine biomedicine, 'infrastructurizing' extant imaginaries while adding on new devices to established routines. The interplay between the new and the old (Gibbon et al. 2018), and the local and global, or the contexts in which genomic technologies are adopted and the shape of these technologies, is already well documented, particularly in regard to health care systems and health care infrastructures (Cambrosio et al. 2018; Parthasarathy 2012; Aarden 2016; Aarden et al. 2009; Zeng et al. 2016). However, the case at hand suggests that in our contemporary worlds, such 'contexts' can also take a more subpolitical shape and include elements of broadly shared imaginaries or transnational epistemic networks of biomedical professionals, which might be amenable to be infrastructurized. Thus, the case of the emergence of NIPT in Vienna can also direct our attention to the redistribution of agency among commercial pioneers, biomedical professionals, and epistemic networks in the emergence of genomic medicine, suggesting that the emergence of genomic medicine might also be tied to a redistribution of agency and a new "fabrication of power" (Jasanoff and Kim 2015).

Acknowledgments Open access funding provided by Austrian Science Fund (FWF). I would like to thank all those experts in Austria, who have set aside time for interviews and conversations with me. I could not have written this article without them. Moreover, I would also like to thank a number of colleagues and friends, who provided support in various ways. I am grateful to Mianna Meskus for her encouragement after the presentation of an earlier version of this paper, to Christian Haddad for pointing me to the notion of "vanguard visions", and to Ulrike Felt for making me aware of "punctualizations". Moreover, I would like to thank Max Fochler, who provided detailed and helpful comments on an earlier draft of this article, and Erik Aarden, who read a more mature draft and encouraged me to submit it. Winnie Wendelin has helped me to compile the bibliography. Last but not the least, I am grateful to the three

reviewers for their careful reading and their insightful comments. They have helped to improve this article. All remaining shortcomings of this article are my responsibility.

Funding The research, writing and copy-editing of this paper have been enabled by a grant funded by the Austrian Science Fund (FWF): T811-G27.

References

Aarden, E., I. Van Hoyweghen, R. Vos, and K. Horstman. 2009. Providing preimplantation genetic diagnosis in the United Kingdom, The Netherlands and Germany: A comparative in-depth analysis of health-care access. *Human Reproduction* 24 (7): 1542–1547.

Aarden, E. 2016. Translating genetics beyond bench and bedside: A comparative perspective on health care infrastructures for 'familial' breast cancer. *Applied & Translational Genomics* 11: 48–54.

Aarden, E. 2017. Projecting and producing 'usefulness' of biomedical research infrastructures; or why the Singapore Tissue Network closed. *Science and Public Policy* 44 (6): 753–762.

Agarwal, A., L.C. Sayres, M.K. Cho, R. Cook-Deegan, and S. Chandrasekharan. 2013. Commercial landscape of noninvasive prenatal testing in the United States. *Prenatal Diagnosis* 33 (6): 521–531.

Akrich, M. 1992. The de-scription of technical objects. In *Shaping Technology/Building Society. Studies in sociotechnical change. Inside technology*, ed. W.E. Bijker and J. Law, 205–224. Cambridge, MA and London: MIT Press.

Allyse, M., L.C. Sayres, J.S. King, M.E. Norton, and M.K. Cho. 2012. Cell-free fetal DNA testing for fetal aneuploidy and beyond: Clinical integration challenges in the US context. *Human Reproduction* 27 (11): 3123–3131.

Allyse, M., M.A. Minear, E. Berson, S. Sridhar, M. Rote, A. Hung, and S. Chandrasekharan. 2015. Noninvasive prenatal testing: A review of international implementation and challenges. *International Journal of Women's Health* 7: 113–126.

Anon. 2014. *40 Jahre Mutter-Kind-Pass. Ein Symposium der Österreichischen Ärztekammer*. Wien: Verlagshaus der Ärzte.

Ariosa Diagnostics, Inc. (2012) Clinical utility of harmony(TM) prenatal test, a non-invasive prenatal test, in general screening population demonstrated in new study. Cision PR Newswire, 5 September, https://www.prnewswire.com/news-releases/clinical-utility-of-harmonytm-prenatal-test-a-non-invasive-prenatal-test-in-general-screening-population-demonstrated-in-new-study-168598566.html. Accessed 5 November 2018.

Ashoor, G., A. Syngelaki, M. Wagner, C. Birdir, and K.H. Nicolaides. 2012. Chromosome-selective sequencing of maternal plasma cell–free DNA for first-trimester detection of trisomy 21 and trisomy 18. *American Journal of Obstetrics and Gynecology* 206 (4): 322.e1–322.e5.

Barry, A. 2001. *Political machines. Governing a technological society*. London and New York: The Athlone Press.

Benn, P., A. Borell, R. Chiu, H. Cuckle, L. Dugoff, B. Faas, S. Gross, J. Johnson, R. Maymon, M. Norton, and A. Odibo. 2013. Position statement from the Aneuploidy Screening Committee on behalf of the Board of the International Society for Prenatal Diagnosis. *Prenatal Diagnosis* 33 (7): 622–629.

Bianchi, D.W., R.L. Parker, J. Wentworth, R. Madankumar, C. Saffer, A.F. Das, J.A. Craig, D.I. Chudova, P.L. Devers, K.W. Jones, and K. Oliver. 2014. DNA sequencing versus standard prenatal aneuploidy screening. *New England Journal of Medicine* 370 (9): 799–808.

Braun, K., and S. Könninger. 2018. Realizing responsibility Institutional routines, critical intervention, and the 'big' questions in the controversy over non-invasive prenatal testing in Germany. *New Genetics and Society* 37 (3): 248–267.

Bundesministerium für Gesundheit und Umweltschutz. 1981. Verordnung des Bundesministers für Gesundheit und Umweltschutz vom 20. Mai 1981 über vordringliche Maßnahmen zur Erhaltung der Volksgesundheit StF: BGBl. Nr. 274/1981.

Callon, M. 1990. Techno-economic networks and irreversibility. In *A sociology of monsters: Essays on power, technology and domination*, ed. J. Law, 132–161. New York: Routledge.

Callon, M., and B. Latour. 1981. Unscrewing the big Leviathan: How actors macro-structure reality and how sociologists help them to do so. In *Advances in social theory and methodology*, ed. K. Knorr-Cetina and A.V. Cicourel, 277–303. London: Routledge and Kegan Paul.

Cambrosio, A., E. Vignola-Gagné, N. Nelson, P. Keating, and P. Bourret. 2018. Genomic platforms and clinical research. In *Routledge handbook of genomics, health and society*, ed. S. Gibbon, B. Prainsack, S. Hilgartner, and J. Lamoreaux, 142–150. London and New York: Routledge.

Casper, M.J., and A.E. Clarke. 1998. Making the Pap smear into the 'right tool' for the job. Cervical Cancer Screening in the USA, circa 1940-95. *Social Studies of Science* 28 (2): 255–290.

Check Hayden, E. 2014. Prenatal-screening companies expand scope of DNA tests. *Nature* 507 (7490): 19.

Chitty, L.S., K.O. Kagan, F.S. Molina, J.J. Waters, and K.H. Nicolaides. 2006. Fetal nuchal translucency scan and early prenatal diagnosis of chromosomal abnormalities by rapid aneuploidy screening: Observational study. *BMJ* 332 (7539): 452–455.

Chitty, L.S., M. Hill, H. White, D. Wright, and S. Morris. 2012. Noninvasive prenatal testing for aneuploidy–ready for prime time? *American Journal of Obstetrics and Gynecology* 206 (4): 269–275.

Chiu, R.W.K., K.C.A. Chan, Y. Gao, V.Y.M. Lau, W. Zheng, T.Y. Leung, C.H.F. Foo, B. Xie, N.B.Y. Tsui, F.M.F. Lun, B.C. Zee, T.K. Lau, C.R. Cantor, and Y.M.D. Lo. 2008. Noninvasive prenatal diagnosis of fetal chromosomal aneuploidy by massively parallel genomic sequencing of DNA in maternal plasma. *Proceedings of the National Academy of Sciences United States of America* 105 (51): 20458–20463.

Clarke, A.E. 2005. *Situational analysis: Grounded theory after the postmodern turn*. Thousand Oaks, CA: SAGE Publications.

Dondorp, W., G. De Wert, Y. Bombard, D.W. Bianchi, C. Bergmann, P. Borry, L.S. Chitty, F. Fellmann, F. Forzano, A. Hall, and L. Henneman. 2015. Non-invasive prenatal testing for aneuploidy and beyond: Challenges of responsible innovation in prenatal screening. *European Journal of Human Genetics* 23 (11): 1438–1450.

Epstein, S. 1995. The construction of lay expertise: AIDS activism and the forging of credibility in the reform of clinical trials. *Science, Technology and Human Values* 20 (4): 408–437.

Fairbrother, G., S. Johnson, T.J. Musci, and K. Song. 2013. Clinical experience of noninvasive prenatal testing with cell-free DNA for fetal trisomies 21, 18, and 13, in a general screening population. *Prenatal Diagnosis* 33 (6): 580–583.

Fan, H.C., Y.J. Blumenfeld, U. Chitkara, L. Hudgins, and S.R. Quake. 2008. Noninvasive diagnosis of fetal aneuploidy by shotgun sequencing DNA from maternal blood. *Proceedings of the National academy of Sciences of the United States of America* 105 (42): 16266–16271.

Felt, U. 2015. Keeping technologies out: Sociotechnical imaginaries and the formation of Austria's technopolitical identity. In *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power*, ed. S. Jasanoff and S.-H. Kim, 104–125. Chicago and London: Chicago University Press.

Felt, U. 2017. Making knowledge, people, and societies. In *The handbook of science and technology studies*, 4th ed, ed. U. Felt, R. Fouché, C.A. Miller, and L. Smith-Doerr, 253–257. Cambridge, MA, and London, England: MIT Press.

Gardner, J., and A. Webster. 2017. Accelerating innovation in the creation of biovalue: The cell and gene therapy catapult. *Science, Technology and Human Values* 42 (5): 925–946.

GenomeWeb. 2012a. Ariosa Inks Deal to Offer Fetal Trisomy Test in UK. GenomeWeb, 18 October, https://www.genomeweb.com/sequencing/ariosa-inks-deal-offer-fetal-trisomy-test-uk. Accessed 5 November 2018.

GenomeWeb. 2012b. Kings College Team Demonstrates Accuracy of Aria's T21 Test. GenomeWeb, 1 February, https://www.genomeweb.com/sequencing/kings-college-team-demonstrates-accuracy-arias-t21-test. Accessed 5 November 2018.

Gibbon, S., B. Prainsack, S. Hilgartner, and J. Lamoreaux. 2018. Introduction to handbook of genomics, health and society. In *Routledge handbook of genomics, health and society*, ed. S. Gibbon, B. Prainsack, S. Hilgartner, and J. Lamoreaux, 1–8. London and New York: Routledge.

Grati, F.R., K. Bajaj, F. Malvestiti, C. Agrati, B. Grimi, B. Malvestiti, E. Pompilii, F. Maggi, S. Gross, G. Simoni, and J.C.P. Ferreira. 2015. The type of feto-placental aneuploidy detected by cfDNA

testing may influence the choice of confirmatory diagnostic procedure. *Prenatal Diagnosis* 35 (10): 994–998.
Gregg, A.R., B.G. Skotko, J.L. Benkendorf, K.G. Monaghan, K. Bajaj, R.G. Best, S. Klugman, and M.S. Watson. 2016. Noninvasive prenatal screening for fetal aneuploidy, 2016 update: A position statement of the American College of Medical Genetics and Genomics. *Genetics in Medicine* 18 (10): 1056–1065.
Griessler, E., and B. Hadolt. 2006. Policy learning in policy domains with value conflicts: The Austrian cases of abortion and assisted reproductive technologies. *German Policy Studies* 3 (4): 693–742.
Hacking, I. 1990. *The taming of chance*. Cambrige: Cambridge University Press.
Hager, A. 2013. Das verschwindende Kind. Profil, 4 March: pp. 64–72.
Haidar, H., C. Dupras, and V. Ravitsky. 2016. Non-invasive prenatal testing: Review of ethical, legal and social implications. *BioéthiqueOnline* 5, http://hdl.handle.net/1866/13176.
Heinsen, L.L. 2018. Moral adherers: Pregnant women undergoing routine prenatal screening in Denmark. In *Selective reproduction in the 21st century*, ed. A. Wahlberg and T.M. Gammeltoft, 69–95. Cham: Palgrave Macmillan.
Hilgartner, S. 2015. Capturing the imaginary: Vanguards, visions and the synthetic biology revolution. In *Science and democracy. Making knowledge and making power in the biosciences and beyond*, ed. S. Hilgartner, C.A. Miller, and R. Hagendijk, 33–55. New York and London: Routledge.
Hogarth, S., and P. Saukko. 2017. A market in the making: The past, present and future of direct-to-consumer genomics. *New Genetics and Society* 36 (3): 197–208.
Hui, L., and D.W. Bianchi. 2017. Noninvasive prenatal DNA testing: The vanguard of genomic medicine. *Annual Review of Medicine* 68 (1): 459–472.
Jasanoff, S. 2015. Future imperfect: Science, technology, and the imaginations of modernity. In *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power*, ed. S. Jasanoff and S.-H. Kim, 1–33. Chicago: Chicago University Press.
Jasanoff, S., and S.-H. Kim (eds.). 2015. *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power*. Chicago: Chicago University Press.
Kagan, K.O., K. Avgidou, F.S. Molina, K. Gajewska, and K.H. Nicolaides. 2006. Relation between increased fetal nuchal translucency thickness and chromosomal defects. *Obstetrics and Gynecology* 107 (1): 6–10.
Kagan, K.O., D. Wright, C. Valencia, N. Maiz, and K.H. Nicolaides. 2008. Screening for trisomies 21, 18 and 13 by maternal age, fetal nuchal translucency, fetal heart rate, free beta-hCG and pregnancy-associated plasma protein-A. *Human Reproduction* 23 (9): 1968–1975.
Kaposy, C. 2018. *Choosing down syndrome. Ethics and new prenatal testing technologies*. Cambridge, MA and London: MIT Press.
Karow, J. 2018. ASHG: Dutch Nationwide NIPT Implementation study sees 42 percent uptake after first year. GenomeWeb, 22 October, https://www.genomeweb.com/molecular-diagnostics/ashg-dutch-nationwide-nipt-implementation-study-sees-42-percent-uptake-after. Accessed 5 November 2018.
Keating, P., and A. Cambrosio. 2012. *Cancer on trial. Oncology as a new style of practice*. Chicago and London: University of Chicago Press.
Kopetzki, C. 2017. Rechtliche Aspekte von PND und PID: Zulässigkeit, Aufklärungspflichten, Haftung. In *Entscheidungsfindung und Entscheidungshilfen am Lebensanfang*, ed. U.H.J. Körtner, C. Kopetzki, M. Kletecka-Pulker, and S. Müller, 81–110. Wien: Verlag Österreich.
Law, J., and A. Mol. 2001. Situating technoscience: An inquiry into spatialities. *Environment and Planning D: Society and Space* 19 (5): 609–621.
Lewis, C., M. Hill, and L.S. Chitty. 2017. Offering non-invasive prenatal testing as part of routine clinical service. Can high levels of informed choice be maintained? *Prenatal Diagnosis* 37 (11): 1130–1137.
Lo, Y.M.D., N. Corbetta, P.F. Chamberlain, V. Rai, I.L. Sargent, C.W.G. Redman, and J.S. Wainscoat. 1997. Presence of fetal DNA in maternal plasma and serum. *The Lancet* 350 (9076): 485–487.
Löwy, I. 2017. *Imperfect pregnancies. A history of birth defects and prenatal diagnosis*. Baltimore: John Hopkins University Press.
Löwy, I. 2015. Norms, values, and constraints: The case of prenatal diagnosis. In *Value practices in the life sciences and medicine*, ed. I. Dussauge, C.-F. Helgesson, and F. Lee, 186–204. Cambridge: Cambridge University Press.
Löwy, I. 2018. *Tangled diagnoses: Prenatal testing, women, and risk*. Chicago and London: The University of Chicago Press.

Mao, J., T. Wang, B.J. Wang, Y.H. Liu, H. Li, J. Zhang, D. Cram, and Y. Chen. 2014. Confined placental origin of the circulating cell free fetal DNA revealed by a discordant non-invasive prenatal test result in a trisomy 18 pregnancy. *Clinica Chimica Acta* 433: 190–193.

Marvin, C. 1990. *When old technologies were new: Thinking about electric communication in the late nineteenth century*. New York and Oxford: Oxford University Press.

McNeil, M., M. Arribas-Ayllon, J. Haran, A. Mackenzie, and R. Tutton. 2017. Conceptualizing imaginaries of science, technology, and society. In *The handbook of science and technology studies*, ed. U. Felt, R. Fouché, C.A. Miller, and L. Smith-Doerr, 435–463. Cambridge, MA, and London: MIT Press.

Meskus, M. 2012. Personalized ethics: The emergence and the effects in prenatal testing. *BioSocieties* 7 (4): 373–392.

Michie, M., and M. Allyse. 2015. Old questions, new paradigms: Ethical, legal, and social complications of noninvasive prenatal testing. *AJOB Empirical Bioethics* 6 (1): 1–4.

Michie, M., S.A. Kraft, M.A. Minear, R.R. Ryan, and M.A. Allyse. 2016. Informed decision-making about prenatal cfDNA screening: An assessment of written materials. *Ethics, Medicine and Public Health* 2 (3): 362–371.

Mol, A., I. Moser, and J. Pols. 2010. Care: Putting practice into theory. In *Care in practice: On tinkering in clinics, homes and farms*, ed. A. Mol, I. Moser, and J. Pols, 7–25. Bielefeld: Transcript-Verlag.

Ngan, O.M.Y., H. Yi, S.Y.S. Wong, D. Sahota, and S. Ahmed. 2017. Obstetric professionals' perceptions of non-invasive prenatal testing for Down syndrome: Clinical usefulness compared with existing tests and ethical implications. *BMC Pregnancy and Childbirth* 17 (1): 285.

Nicolaides, K.H., G. Azar, D. Byrne, C. Mansur, and K. Marks. 1992. Fetal nuchal translucency: Ultrasound screening for chromosomal defects in first trimester of pregnancy. *BMJ* 304 (6831): 867–869.

Nicolaides, K.H., A. Syngelaki, G. Ashoor, C. Birdir, and G. Touzet. 2012. Noninvasive prenatal testing for fetal trisomies in a routinely screened first-trimester population. *American Journal of Obstetrics and Gynecology* 207 (5): 374.e1–374.e6.

Nicolaides, K.H. 2011. Screening for fetal aneuploidies at 11 to 13 weeks. *Prenatal Diagnosis* 31 (1): 7–15.

Norton, M.E., B. Jacobsson, G.K. Swam, L.C. Laurent, A.C. Ranzini, H. Brar, M.W. Tomlinson, L. Pereira, J.L. Spitz, D. Hollemon, and H. Cuckle. 2015. Cell-free DNA analysis for noninvasive examination of trisomy. *New England Journal of Medicine* 372 (17): 1589–1597.

Nuffield Council on Bioethics. 2017. Non-invasive prenatal testing: Ethical questions. Nuffield Bioethics, March, http://nuffieldbioethics.org/wp-content/uploads/NIPT-ethical-issues-full-report.pdf. Accessed 5 November 2018.

Parham, L., M. Michie, and M. Allyse. 2017. Expanding use of cfDNA screening in pregnancy: Current and emerging ethical, legal, and social issues. *Current Genetic Medicine Reports* 5 (1): 44–53.

Parthasarathy, S. 2012. *Building genetic medicine. Breast cancer, technology, and the comparative politics of health care*. Cambridge, MA: MIT Press.

Paul, K.T. 2016. 'Saving lives': Adapting and adopting Human Papilloma Virus (HPV) vaccination in Austria. *Social Science and Medicine* 153: 193–200.

Prainsack, B. 2006. 'Negotiating life': The regulation of human cloning and embryonic stem cell research in Israel. *Social Studies of Science* 36 (2): 173–205.

Ravitsky, V. 2017. The shifting landscape of prenatal testing: Between reproductive autonomy and public health. *Hastings Center Report* 47 (S3): S34–S40.

RIS (Rechtsinformationssystem des Bundes). 2007. Allgemeines Sozialversicherungsgesetz. BGBl. Nr. 189/1955 zuletzt geändert durch BGBl. I Nr. 31/2007, §132c.

Roche. 2014. Roche acquires Ariosa Diagnostics and enters the non-invasive prenatal test (NIPT) and cell-free DNA testing services markets, 2 December, https://www.roche.com/dam/jcr:ae062982-8261-452d-b00f-9b0f07df3431/de/med-cor-2014-12-02-e.pdf. Accessed 5 November 2018.

Salomon, L.J., Z. Alfirevic, F. Audibert, K.O. Kagan, D. Paladini, G. Yeo, N. Raine-Fenning, and I.S.U.O.G. Clinical Standards Committee. 2017. ISUOG updated consensus statement on the impact of cfDNA aneuploidy testing on screening policies and prenatal ultrasound practice. *Ultrasound in Obstetrics and Gynecology* 49 (6): 815–816.

Schmid, M., P. Klaritsch, W. Arzt, H.C. Duba, M. Häusler, E. Hafner, U. Lang, B. Pertl, M. Speicher, and H. Steiner. 2015a. Empfehlung der Österreichischen Gesellschaft für Gynäkologie und Geburtshilfe (ÖGGG), der Österreichischen Gesellschaft für Ultraschall in der Medizin (ÖGUM), der Österreichischen Gesellschaft für Prä- und Perinatale Medizin (ÖGfPPM) und der Österreichischen Gesellschaft für Humangenetik (ÖGH) zum Einsatz von Nicht-invasiven pränatalen Tests (NIPT) zur Analyse der zellfreien DNA (cfDNA) im mütterlichen Blut zum Screening auf fetale Chromosomenstörungen in der klinischen Praxis.

Schmid, M., P. Klaritsch, W. Arzt, T. Burkhardt, H.C. Duba, M. Häusler, E. Hafner, U. Lang, B. Pertl, M. Speicher, and H. Steiner. 2015b. Cell-free DNA testing for fetal chromosomal anomalies in clinical practice: Austrian-German-Swiss recommendations for non-invasive prenatal tests (NIPT). *Ultraschall in der Medizin* 36 (5): 507–510.

Schuchter, K., E. Hafner, G. Stangl, M. Metzenbauer, D. Höfinger, and K. Philipp. 2002. The first trimester 'combined test' for the detection of Down syndrome pregnancies in 4939 unselected pregnancies. *Prenatal Diagnosis* 22 (3): 211–215.

Schwennesen, N., M.N. Svendsen, and L. Koch. 2010. Beyond informed choice: Prenatal risk assessment, decision-making and trust. *Clinical Ethics* 5 (4): 207–216.

Slota, S.C., and G.C. Bowker. 2017. How infrastructures matter. In *The handbook of science and technology studies*, Forth ed, ed. U. Felt, R. Fouché, C.A. Miller, and L. Smith-Doerr, 529–554. Cambridge, MA and London, England: MIT Press.

Snijders, R.J.M., P. Noble, N. Sebire, A. Souka, and K.H. Nicolaides. 1998. UK multicentre project on assessment of risk of trisomy 21 by maternal age and fetal nuchal-translucency thickness at 10–14 weeks of gestation. *The Lancet* 352 (9125): 343–346.

Sparks, A.B., C.A. Struble, E.T. Wang, K. Song, and A. Oliphant. 2012. Noninvasive prenatal detection and selective analysis of cell-free DNA obtained from maternal blood: Evaluation for trisomy 21 and trisomy 18. *American Journal of Obstetrics and Gynecology* 206 (4): 319.e1–319.e9.

Strange, H. 2017. The fetus as a patient: Professional and patient discourse. In *The fetus as a patient*, ed. D. Schmitz, A. Clarke, and W. Dondorp, 78–93. London: Routledge.

Timmermans, S., and M. Berg. 2003. The practice of medical technology. *Sociology of Health & Illness* 25 (3): 97–114.

Timmermans, S., and M. Buchbinder. 2013. *Saving babies? The consequences of newborn genetic screening*. Chicago and London: The University of Chicago Press.

Timmermans, S., and S. Shostak. 2016. Gene worlds. *Health: An Interdisciplinary Journal for the Social Study of Health, Illness and Medicine* 20 (1): 33–48.

Turrini, M. 2014. The controversial molecular turn in prenatal diagnosis. CGH-array clinical approaches and biomedical platforms. *Tecnoscienza* 5 (1): 115–139.

Vassy, C., S. Rosman, and B. Rousseau. 2014. From policy making to service use. Down's syndrome antenatal screening in England, France and the Netherlands. *Social Science and Medicine* 106: 67–74.

Vries, G.De. 2007. What is political in sub-politics? How Aristotle might help STS. *Social Studies of Science* 37 (5): 781–809.

Wahlberg, A., and T.M. Gammeltoft. 2018. Introduction: Kinds of children. In *Selective reproduction in the 21st century*, ed. A. Wahlberg and T.M. Gammeltoft, 1–24. Cham: Palgrave Macmillan.

Wapner, R.J., J.E. Babiarz, B. Levy, M. Stosic, B. Zimmermann, S. Sigurjonsson, N. Wayham, A. Ryan, M. Banjevic, P. Lacroute, and J. Hu. 2015. Expanding the scope of noninvasive prenatal testing: Detection of fetal microdeletion syndromes. *American Journal of Obstetrics and Gynecology* 212 (3): 332.e1–332.e9.

Weiss, R.S. 1995. *Learning from strangers: The art and method of qualitative interview studies*. New York: Free Press.

Wieser, B. 2006. Inescapable decisions. Implications of new developments in prenatal testing. *Science, Technology & Innovation Studies* 2 (1): 41–56.

Wong, F.C.K., and Y.M.D. Lo. 2016. Prenatal diagnosis innovation: Genome sequencing of maternal plasma. *Annual Review of Medicine* 67 (1): 419–432.

Zeng, X., L. Zannoni, I. Löwy, and S. Camporesi. 2016. Localizing NIPT: Practices and meanings of noninvasive prenatal testing in China, Italy, Brazil and the UK. *Ethics, Medicine and Public Health* 2 (3): 392–401.

Ingrid Metzler Studied political science at the University of Rome, *LaSapienza*, the University of Innsbruck, and the University of Vienna. Since 2016, she is a post-doc at the University of Vienna's Department of Science and Technology Studies. In her research, she explores the connections between the emergence of the biosciences and transformations in contemporary democracies.